COMPARATIVE EVALUATION OF THE EFFECTS OF TWO CERAMIC FINISHING SYSTEMS AND DIAMOND POLISHING PASTE ON THE SURFACE ROUGHNESS OF TWO CERAMIC MATERIALS USED FOR CERAMO-METAL RESTORATIONS -AN IN VITRO STUDY

Dissertation submitted to

THE TAMILNADU Dr. M. G. R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

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CERTIFICATE

This is to certify that this dissertation titled "COMPARATIVE EVALUATION OF THE EFFECTS OF TWO CERAMIC FINISHING SYSTEMS AND DIAMOND POLISHING PASTE ON THE SURFACE ROUGHNESS OF TWO CERAMIC MATERIALS USED FOR CERAMO-METAL RESTORATIONS - AN IN VITRO STUDY" a bonafide record of work done by Dr. CHERRY ANMOL under our guidance and to our satisfaction during her postgraduate study period 2006-2009.

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY, in partial fulfillment for the award of the Degree of MASTER OF DENTAL SURGERY– PROSTHODONTICS, BRANCH VI. It has not been submitted (partial or full) for the award of any other degree or diploma.

GUIDED BY:

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Dr. N.S.Azhagarasan, M.D.S.,
Professor & H.O.D,
Dept. of Prosthodontics,
Ragas Dental College and Hospital,
Chennai.

Dr. Saket Miglani, M.D.S.,
Reader,
Dept. of Prosthodontics,
Ragas Dental College and Hospital, Uthandi,
Uthandi, Chennai.

Dr. S. Ramachandran, M.D.S.,
Principal,
Ragas Dental College and Hospital,
Uthandi, Chennai.

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INTRODUCTION

Dental ceramics are widely used in dental practice as material of choice for porcelain-fused-to-metal or all-ceramic restorations in crown and bridge prosthodontics and as laminate veneers in cosmetic dentistry, because of their natural appearance.[31]

Porcelain fused to metal restorations account for more than 80% of the restorations made worldwide. [12] These are popularly used in prosthodontics because of their refractive nature, hardness, biocompatibility and chemical inertness. These have metal substructures supporting a ceramic veneer that is mechanically and chemically bonded. Among the various types of veneering porcelain available for metal ceramic restorations, the traditional feldspathic porcelain is still widely used despite numerous scientific reports of their harmful behavior regarding increased wear of the opposing dentition. The fluorapatite leucite porcelain claims to have smoother surface topography, lower abrasiveness towards the enamel and improved color which accounts for its increased use in recent times.[1, 34] The strong life-like appearance of the completed metal ceramic restoration results from a surface glaze, formed on additional firing of the restoration.[1, 12, 31, 34]

Ideally, ceramic restorations should retain their intact surface glaze. However, occasions will arise when ceramic restorations require adjustments in circumstances that preclude reglazing, for example chair side adjustment of ceramic restorations for shape, contour, occlusion and surface finish.[30, 51] In the clinical set up it is not possible to reglaze the restorations due to practical constraints. In such situations the surfaces tends to become rough. The Rough ceramic surfaces abrade opposing teeth and/or restorations.[14, 15, 32, 53] Rough porcelain surfaces also significantly reduce the strength of ceramic restorations and make them prone to fracture.[31]

Roughness of intraoral hard surfaces is a major cause for adhesion and retention of oral microorganisms.[12] This will lead to excessive plaque accumulation, gingival irritation, increased surface staining, and poor or suboptimal esthetics of the restored teeth and thereby increasing the risk of dental caries and periodontal disease. In such situations, roughness must be smoothened to render the surface acceptable to the patient and make it less likely to abrade opposing tooth structure or restorative materials. The effective finishing and polishing of dental restorations not only result in optimal aesthetics and longevity of restored teeth, but also provide for acceptable oral health of soft tissues and marginal integrity of the restorative interface.[25, 26]

The adjusting, contouring, and finishing procedures for metal ceramic restorations play a critical role in achieving both proper function and optimal esthetics. Thus it has become imperative to consider the various available ceramic finishing systems to recreate the lost smoothness of the abraded surfaces to obtain optimal biocompatibility. A number of mechanical polishing techniques are described in the literature and have been compared to the gold standard given by the original glaze. Some authors initially demonstrated the superior smoothness of glazed porcelain.[11, 41, 42] Others, however, favour mechanical polishing and concluded that intraoral polishing of porcelain can equal or surpass the smoothness of glazed porcelain.[19, 20, 30, 49, 51] Today, it is recognized that improved esthetic results are obtained by polishing.[3, 9, 22, 39] The ultimate goal of mechanical finishing and polishing is the attainment of a well polished surface which can substitute for glazed porcelain.

Studies comparing the efficacy of various smoothening and polishing systems for metal ceramic restorations are carried out either qualitatively or quantitatively. Most studies have focused on the qualitative analysis of the ceramic surface.[2, 11, 44, 45, 47, 51] Fewer studies have examined the surface quantitatively.[24, 49, 52] Some studies have both qualitative and quantitative assessment following different finishing procedures.[3, 16, 17, 19, 20, 27, 42, 50] The analysis of the surface both qualitatively and quantitatively can aid in obtaining better inferences.

In light of the above, the present in vitro study was designed to qualitatively and quantitatively evaluate and compare the effect of two ceramic finishing systems and diamond polishing paste had on the surface texture of two ceramic materials used for ceramo-metal restorations.

The objectives of the study included:

1. To qualitatively evaluate and compare the effects of two ceramic finishing systems on the surface roughness of the test samples of feldspathic porcelain using scanning electron microscope after Autoglazing, following abrasion and finishing with two test finishing systems, and finally after polishing.
2. To qualitatively evaluate and compare the effects of two ceramic finishing systems on the surface roughness of the test samples of fluorapatite leucite porcelain using scanning electron microscope after Autoglazing, following abrasion and finishing with two test finishing systems, and finally after polishing.
3. To qualitatively compare the effects of two ceramic finishing systems on the surface roughness between the test samples of feldspathic and the fluorapatite leucite porcelain using scanning electron microscope after Autoglazing, following abrasion and finishing with two test finishing systems, and finally after polishing.
4. To quantitatively evaluate and compare the effects of two ceramic finishing systems on the surface roughness of the test samples of feldspathic porcelain using profilometer after Autoglazing, following abrasion and finishing with two test finishing systems, and finally after polishing.

5. To quantitatively evaluate and compare the effects of two ceramic finishing systems on the surface roughness of the test samples of fluorapatite leucite porcelain using profilometer after Autoglazing, following abrasion and finishing with two test finishing systems, and finally after polishing.

6. To quantitatively compare the effects of two ceramic finishing systems on the surface roughness between the test samples of feldspathic and the fluorapatite leucite porcelain using profilometer after Autoglazing, following abrasion and finishing with two test finishing systems, and finally after polishing.

7. To obtain correlations, if any, of the surface roughness values obtained by quantitative and qualitative analysis of feldspathic and the fluorapatite leucite porcelain systems

REVIEW OF LITERATURE

Clayton J A et al (1970)[13] did this study to compare the surface roughness, following final finishing and polishing, of pontics constructed from cast gold, acrylic resin, and glazed porcelain. The surface roughness of the sample pontics was measured with a profilometer. Statistical analysis indicated that the test surfaces of glazed porcelain were significantly rougher than the polished test surfaces of either acrylic resin or cast gold. There was no significant difference in surface roughness between the polished acrylic resin and polished cast gold sample pontic surfaces.

Monasky G E et al (1971)[32] investigated the wear caused by varying combinations of tooth enamel, gold, and porcelain, with particular emphasis on the affect of variations in the surface finish of the porcelain on the resultant wear. They concluded that: (1) the rougher the porcelain surface, the more rapid is the rate of tooth wear. Rough ground porcelain surfaces produced excessive wear rates, and if the glaze is broken on porcelain, it must be repolished. (2) Porcelain surfaces in contact with tooth structure tend to wear rapidly at first until a "polish" of the porcelain surface is obtained. This functional polishing of the porcelain reduced the wear rate on opposing teeth. (3) Gold wears rapidly when in contact with porcelain. Polishing of porcelain occurs very slowly if at all when in contact with gold. Thus, if porcelain is to be used in opposition to gold, it is essential that the porcelain be smooth and well polished.

Morrow R M et al (1973)[33] evaluated five commonly used methods for polishing porcelain denture teeth. Each tooth was rated on a three point scale by comparing its polished surface to the glazed surface of the control tooth. The statistical analysis found that polishing methods 2, 4, and 5 were significantly better than polishing methods 1 and 3. However, additional factors, such as the reduction of tooth thickness, the length of the polishing time, and the cost, should be considered when selecting the "best" over-all polishing method for a specific purpose.

Barghi N et al (1975)[6] ascertained microscopically, the surface appearance of both air-fired and vacuum- fired porcelain following various alterations. They found that vacuum-fired had a smoother surface than air-fired porcelain. The relative absence of bubbles allowed the vacuum-fired porcelain to be sanded and polished to a significantly superior finish. They concluded that, regardless of the usual polishing techniques, a final glaze presented the most acceptable surface.

Barghi N et al (1976)[7] conducted this study to determine whether or not the finish attained prior to glazing affected the final surface texture of glazed porcelain and to examine for differences between the surface appearance of natural and low-fusing glazes. They concluded that a smooth surface can be obtained by glazing after grinding and there was no need for sanding or polishing with a rubber wheel. They also found that a low-fusing glaze gave a slightly smoother surface than a natural glaze and the low-fusing glaze may be added at any stage of polishing, as the results will be the same.

Sulik W D et al (1981)[51] in their article described a polishing technique for fully matured porcelain which may be substituted for reglazing and also compared the polished and glazed surfaces using the Scanning electron microscope. The technique made use of a hard rubber wheel, fine wet pumice and wet tin oxide. A comparison of the polished and naturally glazed porcelain surfaces of vacuum-fired porcelain appeared similar both clinically and under an SEM.

Schlissel E R et al (1980)[47] evaluated eleven commonly used methods of adjusting and polishing vacuum-fired porcelain denture teeth. A qualitative assessment of the postadjustment surface roughness, as compared to an unaltered specimen, was made by an electron micrograph examination of the surface finish of each repolished porcelain denture tooth. Three methods 7, 10, 11 (7- Abrasive wheel with a slow-speed dental handpiece, hard rubber wheel with a slow-speed dental handpiece, slurry of medium-grade pumice on a rag wheel mounted on a dental lathe, and slurry of flour of pumice on a rag wheel mounted on a dental lathe, 10- Abrasive stone with a slow-speed dental handpiece, hard rubber wheel with a slow-speed dental handpiece, slurry of medium-grade pumice on a rag wheel mounted on a dental lathe, and slurry of flour of pumice on a rag wheel mounted on a dental lathe, and 11- Polishing kit with a sequence of four abrasives in a slow speed dental handpiece) produced finished surfaces comparable to the unaltered tooth. The best surface finish was produced by using the proprietary kit in method 11.

Obregon A et al (1981)[36] did a study to compare the effects of various opaque and porcelain surface textures on two different shades of porcelain. A spectrophotometer was used to measure the color of the porcelain samples when the porcelain and opaque textures were modified. The results showed that porcelain surface texture, whether rough or smooth, did not make a difference in Hue. The smooth surface porcelain texture increased the Value of shade B1 compared to the rough porcelain surface. The interactions that occur between the texture of porcelain and opaque affecting color are complex phenomena and may be related to the modification of light by transmission, absorption, refraction, scattering, and reflection.

Smith G A et al (1981)[50] did a study to investigate the surface finish which can be achieved on trimmed porcelain surfaces by the use of a series of discs (Sof-Lex) designed for finishing composite restorations. The surface finish achieved with the Sof-Lex discs is compared with that produced by abrasives commonly used for trimming porcelain surfaces. Two-thirds of the glazed upper surface of 24 test specimens were trimmed using one of the procedures: (1) Diamond stone, (2) Busch silent wheel, (3) Busch silent wheel followed by impregnated rubber wheel, (4) Coarse Sof-Lex disc, (5) Busch silent wheel followed by medium Sof-Lex disc, (6) Busch silent wheel followed by medium, fine and superfine Sof-Lex discs, (7) Diamond stone followed by coarse and medium Sof-Lex discs, (8) Diamond stone followed by coarse, medium, fine and superfine Sof-Lex discs. Scanning electron microscopy and a surfometer have been used to study and compare the appearance and profiles of the surfaces of glazed specimens of vacuum-fired aluminous porcelain. The results demonstrate that the surface finish of trimmed porcelain can be improved considerably by the use of a series of discs designed for finishing composite restorations. The optimum finishing procedure will do little to improve the strength of trimmed porcelain restorations, but it may limit surface accumulations of plaque and stain and reduce the friction and abrasion effects on opposing occlusal surfaces.

Klausner L H et al (1982)[30] evaluated four different porcelain polishing sequences, and the resulting polished surfaces were compared to an unaltered glazed surface. The sequence included (1) superfine diamond, Dedeco wheels, and levigated alumina; (2) Shofu porcelain polishing system; (3) superfine diamond, Cratex wheel, Burlew disk, and levigated alumina; (4) Jelenko porcelain carving and polishing wheels. No significant differences were found between the final polished surfaces and the initial autoglazed surfaces for any of the four test sequences. Significant differences were found between comparable abrasives among the polishing sequences, as well as between steps within a single polishing sequence.

Newitter D A et al (1982)[35] compared the effectiveness of commonly available adjustment (grinding) methods and polishing (finishing) methods used in different combinations. Six methods for initial reduction of the porcelain on porcelain-bonded-to-metal crowns were evaluated for their effects on the smoothness of finished unglazed surfaces.

Eleven methods for finishing ground porcelain surfaces were evaluated for smoothness of the surfaces produced. Methods employing finishing wheels followed by pumice or porcelain polishing paste produced smoother surfaces than other methods. This information can be helpful in the selection of techniques for initial reduction and finishing of porcelain-baked-to-metal in the absence of glazing.

Christensen G J (1986)[12] conducted a survey to determine the attitudes and practices of dentists regarding porcelain-fused-to-metal restorations. The survey revealed the following:(1) Porcelain-fused-to-metal crowns are the most commonly used crowns in dentistry, (2) Cast gold crowns are infrequently placed compared to PFM, (3) Most dentists consider PFM crowns extremely successful restorations; (4) Although porcelain occlusal surfaces are considered acceptable by most dentists, dentists prefer metal on occlusal surfaces for restorations in their own mouths; (5) The anterior ¾ crown is infrequently placed, but the posterior ¾ crown is commonly used; (6) The Cerestore crown is gaining acceptance; (7) Porcelain-jacket-crown use is reduced, but still a viable alternative; (8) The most desired improvement for PFM restorations was less wear on opposing teeth.

Zalkind M et al (1986)[55] examined the degrees of roughness of porcelain after subjecting it to abrasive techniques and natural (self) glazing. In their study they found that glazing the porcelain surface reduced by an abrasive instrument would not reduce the resulting roughness. To produce a smooth surface it was needed to sandblast the abraded surface with aluminum oxide before retiring to produce a natural glaze.

Haywood V B et al (1988)[19] found that techniques for placement of etched porcelain laminate veneers require that the glazed porcelain veneer be cemented prior to finishing and polishing. Using scanning electron microscopy (SEM) and specular reflectance, the surface texture of autoglazed porcelain was compared with that of polished porcelain. Emphasis was placed on those instruments which are suitable for gingival and interproximal finishing. Finishing with a fine diamond instrument followed only by diamond polishing paste produced an unacceptable surface. A finish equal or superior in smoothness to glazed porcelain was achieved through the use of a series of finishing grit diamonds (Micron Finishing System) followed by a 30-fluted carbide bur and diamond polishing paste. Other finishing combinations produced surface textures which were not as smooth as glazed porcelain, but which were better than that attained by the diamond polishing paste alone.

Haywood V B et al (1989)[20] evaluated several experimental instruments and materials to determine if polishing could be done more efficiently. Scanning electron microscopy was used to evaluate the surface texture produced by different combinations of experimental instruments applied with high and moderate speed, wet and dry, to porcelain disks. No sequence matched the polished standard. However, the optimum surface texture was obtained with diamond instruments (with progressively smaller particle sizes) used at a moderate speed with water, followed by a 30-fluted carbide bur at high speed and dry, then diamond polishing paste on a webbed rubber cup. In all polishing sequences tested, the best results were obtained with each individual instrument when diamond instruments were used at moderate speed wet, and when carbide instruments were used at high speed dry.

Campbell S D (1989)[11] in this study used scanning electron microscopy to evaluate the effect of polishing procedures on two all-ceramic crown materials (Dicor and Cerestore).The “as formed,” unpolished specimens of both Dicor and Cerestore materials presented a rough surface. It was found that any attempt to polish the Cerestore coping material resulted in an extremely rough surface. Finishing of the Dicor ceramic resulted in a smoother but pitted surface. Polishing of both ceramic materials resulted in a surface that was rougher than the glazed metal ceramic controls. The smoothest finish was obtained when the glazed veneer (Cerestore) and shaded porcelain (Dicor) were applied to the all-ceramic materials.

Brackett S E et al (1989)[8] evaluated the flexural strengths of fine porcelains commonly used in the all-porcelain margin technique and the effect of surface treatment on the flexural strength. Thirty samples were made by using each of five different porcelain margin systems. The subgroups received different surface treatments as follows: (1) autoglaze, (2) overglaze, and (3) autoglaze and polish. A three-point flexural test was used to test the specimens on a universal testing machine. Crystar shoulder porcelain with distilled water as the binder was significantly stronger than the other porcelains tested, and porcelain treated with an overglaze was stronger than porcelain treated with autoglaze or autoglaze and polish.

Goldstein R E (1989)[18] evaluated that regardless of the color, shape or attention to detail, the qualities and objectives of finishing do require extra time to adequately finish all restorations. A properly finished restoration should have the following qualities and objectives. Qualities include: (1) A well finished margin. This implies no overhang, void, or extension of restorative material that could interfere with tissue health (2) A sufficiently smooth surface that will not attract bacterial plaque or food stains (3) Suitable surface texture that blends in or matches adjacent or opposing natural teeth (4) Color matching of the existing adjacent, opposing, or preselected tooth shade (5) A surface finish devoid of too obvious contour, finishing bur, or diamond marks. Objectives include: (1) To improve and finalize restoration margins and contours that will help make the restoration biocompatible with both tooth and tissue (2) To develop maximum surface luster to enhance esthetics, reduce stain and plaque retention, plus minimize wear and fracture potential.

Wiley M G (1989)[53] in this article explored the potentially destructive nature of dental porcelain placed on the occluding surface of prosthodontic restorations. In depth knowledge of physical properties of dental porcelains is a necessity. Comprehensive treatment planning that includes a total evaluation of the patient's occlusal function and dysfunction is critical. Finally viable material and treatment options are presented along with methods to help control the effects of porcelain if its use is mandated. Author suggested that all occluding ceramic surfaces should be highly polished and glazed after adjustments and before cementation.

Raimondo R L et al (1990)[44] compared the finishes on dental porcelain polished with four different polishing paste systems with oven reglazing and with a porcelain adjustment kit without a polishing paste. The polished/reglazed samples were rated according to quality of finish by independent observers and by scanning electron microscope. On the basis of visual examination, two of the polishing paste systems tested was found to produce a surface equal to or better than oven glazing. On the basis of SEM examination, oven glazing was found to produce a better surface than the other polishing methods. Not all porcelain polishing systems produce a surface comparable to oven-glazed porcelain, and porcelain polishing systems should be chosen carefully.

Brewer J D et al (1990)[9] in this study determined that whether visual inspection differences exist between glazed and polished porcelain surfaces. All crowns were initially autoglazed. For phase 1 observations, six crowns were air abraded and polished and six retained their glazed surface. For phase 2 observations, the surface treatments were reversed. Phase 1 polished and glazed crowns had different means for outline form sharpness, porosity, reflectance, dullness, and general esthetic appearance. Phase 2 crowns were different for dullness. Polished and glazed crowns alike were duller at phase 1 than at phase 2.Glazed crowns were different between phases for reflectance and general esthetic appearance.

Significant differences occurred among raters with polished and glazed crowns for several variables.

Goldstein G R et al (1991)[17] According to author, research has indicated that polishing ground porcelain is essential to control the wear of opposing occlusal surfaces and reduce the inflammation of contacted soft tissue. Fine popular methods for polishing porcelain were evaluated by use of a profilometer, SEM, normal vision. Seventy disks, 35 Biobond disks and 35 Ceramco disks were roughened with a green stone and polished with one of the methods according to the manufacturers' directions. Brasseler, Dedeco, Dentsply, and Shofu porcelain polishing systems were suitable for restoring ground porcelain. However, clinical evaluations correlated to the profilometer and SEM readings revealed that the Brasseler system was superior for polishing than Ceramco porcelain, whereas the Den-Mat system was unacceptable.

Patterson C J W et al (1991)[41] studied the effect of porcelain refinishing kit on Vita VMK bonded porcelain qualitatively and quantitatively using scanning electron microscope and surface profilometer, respectively. The kit proved incapable of restoring a surface glaze to porcelain adjusted using a fine (red band) diamond bur, but was capable of reducing significantly the surface roughness (Ra) of adjusted porcelain. The importance of distinguishing between the integrity of the surface glaze and measurements of surface roughness was discussed. Confining the application of refinishing procedures to the surface adjusted is important to avoid unnecessary removal of the original surface glaze.

Palmer D S et al (1991)[38] in this study determined the effect of castable ceramic, with and without shading porcelain applied, on enamel wear. The wear produced by conventional dental porcelain was used as a control. Enamel wear was calculated from microscopic measurements of the enamel cones before and after abrading. Significant differences were found between castable ceramic with and without shading porcelain and between conventional dental porcelain and castable ceramic with shading. These findings suggest that castable ceramic with shading porcelain should not be used in regions that will function against opposing natural teeth.

Jacobi R et al (1991)[22] compared a type III gold alloy and six different ceramic surfaces by securing them in an abrasion machine opposing extracted teeth to determine their relative abrasiveness and resistance to wear. The rankings of restorative materials from least abrasive to most abrasive were: gold alloy, polished; cast ceramic, polished; porcelain, polished; cast ceramic, polished and shaded; porcelain, polished and glazed; cast ceramic, cerammed skin shaded; and cast ceramic, cerammed skin unshaded. The ranking of materials from most wear-resistant to least wear-resistant was: gold alloy, cast ceramic cerammed, cast ceramic cerammed and shaded, porcelain polished, porcelain glazed, cast ceramic polished and shaded, and cast ceramic polished.

Patterson C J W et al (1992)[42] investigates the efficacy of commercial porcelain refinishing kit, which are claimed to restore the surface finish on porcelain after adjustments in circumstances that preclude reglazing. In this study, they investigates the efficacy of one such kit in restoring a Vitadur N porcelain surface finish after grinding with fine (30 µm grit-red band) and extra-fine (15 µm grit-yellow band) high-speed diamond burs. Randomly selected examples of surfaces created during refinishing were subjected to scanning electron microscopy and to surface profilometry tracings. Although refinishing after grinding with a 15 µm grit bur produced surfaces significantly smoother than on specimens previously ground with the 30 µm grit burs, the surfaces remained significantly rougher than when originally glazed. It is concluded that, using the type of kit tested, burs of a grade finer than the existing

15 µm grit yellow band types would be appropriate for porcelain adjustments to permit subsequent refinishing to a surface smoothness comparable to the original glaze.

Scurria M S et al (1994)[49] found that conventional and CAD-CAM ceramic restorations often require adjustments that results in a need to reduce surface roughness. Surface roughness resulting from fine polishing systems on two ceramics was assessed. Five profilometer average roughness measurements (Ra) were taken of five replications of each step in each sequence. Controls were autoglazed. Ceramco II and Dicor MGC ceramic specimens milled with Cerec diamond wheel. Feldspathic porcelain could be polished smoother than glazed. Dicor ceramic could be polished smoother than Ceramco II Ceramic. Finishing diamond points followed by diamond gels produced the smoothest surface. A 30-fluted carbide did not improve smoothness as used. The aluminum oxide point followed by aluminum oxide pastes was equivalent to finishing diamonds and gels for Dicor ceramic.

Jagger D C et al (1994)[23] performed abrasive wear tests on unglazed, glazed, and polished porcelain stud specimens using human enamel as the opposing plate specimens. The wear tests were carried out on a wear machine that was specifically designed to simulate the masticatory cycle. The amount of enamel wear produced by both glazed and unglazed porcelain was similar; however, that produced by polished porcelain was substantially less. Investigation of the glazed porcelain surface showed that the glaze was removed in less than 2 hours of wear on the machine.

Ward M T et al (1995)[52] found that intraoral porcelain polishing is an important consideration in many restorative and esthetic procedures. Several porcelain polishing systems as well as improved ceramics are now commercially available. This study evaluated the efficacy of eight different intraoral polishing techniques on three opalescent porcelains. The surface roughness (Ra) of the opalescent porcelains was measured before and after the polishing procedures with a profilometer. These results were then compared to self-glazed and overglazed control groups. Five of the techniques tested produced surfaces smoother than glazing. The use of a 30-fluted carbide bur before diamond polishing paste produced the smoothest surfaces.

Fuzzi M et al (1996)[16] analyzed the surface roughness of Vita VMK porcelain following oven glazing and eight grinding/polishing treatments qualitatively using scanning electron microscope and quantitatively using a profilometer. Scanning electron microscopy evaluation found oven glazing produced a better surface than other polishing methods. On the basis of the profilometric examination, the best average roughness value was obtained using diamond instruments with progressively smaller particle sizes (30, 15, and 8 microns). Scanning electron microscopy analysis showed that all the treatments left the surfaces partially porous and cracked; however, the glazed surface yielded the best result. Although no significant differences were detected for the different treatments, the use of a 30-microns diamond instrument produced a rougher surface..

Kelly J R et al (1996)[29] in this article presents a brief history of dental ceramics and offers perspectives on recent research aimed at the further development of ceramics for clinical use, at their evaluation and selection, and very importantly, their clinical performance. Notable research was highlighted regarding (1) wear of ceramics and opposing enamel, (2) polishability of porcelains, (3) influence of firing history on the thermal expansion of porcelains for metal ceramics, (4) machining and CAD/CAM as fabrication methods for clinical restorations, (5) fit of ceramic restorations, (6) clinical failure mechanisms for all-ceramic prosthesis, (7) chemical and thermal strengthening of dental ceramics, (8) intraoral porcelain repair and (9) criteria for selection of the various ceramics available .It is found that strong scientific and collaborative foundations exist for the continued understanding and improvement of dental ceramic systems.

Jefferies S R (1998)[25] presented an overview of basic principles of abrasive science as they relate to the finishing and polishing of dental restorations. This discussion considers several commercial products in terms of research into their use and optimal application. Additional consideration is given to important technique considerations in the application of various finishing and polishing devices and materials. As proper finishing and polishing of dental restorations are important aspects of clinical restorative procedures that enhance both esthetics and longevity of restored teeth. Effective use of rotary cutting burs and bonded, coated, and loose abrasives can greatly simplify and improve the effectiveness of finishing and polishing procedures.

Al-Wahadni A M et al (1998)[3] presented a review of a number of studies that have examined the visual and microscopic appearance and roughness of glazed, unglazed and polished porcelain surfaces using techniques such as, scanning electron microscopy and surface Profilometry. They agreed that glazed porcelain provides a smooth and dense surface. Others have shown that polishing can produce an equally smooth surface, which may even be esthetically better. Still others supported the use of polishing as an alternative to glazing. However, reports have shown that unglazed porcelain is more abrasive than glazed.

Al-Hiyasat A S et al (1999)[1] in this in vitro study, investigated the wear of human enamel and 3 dental ceramics: a conventional porcelain (Vitadur Alpha), a low-fusing hydrothermal ceramic (Duceram-LFC), and a machinable ceramic (Vita Mark II) in a 3-body wear test. The abrasiveness of Alpha porcelain and Duceram-LFC ceramic was similar, yet both were significantly more abrasive than Vita Mark II ceramic. In addition, Vita Mark II was the most wear-resistant ceramic and Duceram-LFC ceramic the least resistant.

Al-Wahadni A M et al (1999)[4] performed an in vitro investigation into the wear effects of glazed, unglazed and refinished dental porcelain on an opposing material. The investigation confirmed that the best finish and least abrasive surface were produced by glazing of porcelain. The finish produced by intermediate components of the proprietary finishing kit did not reduce the abrasiveness of the porcelain surface. It was necessary to complete the polishing sequence with diamond paste to achieve a surface which approached the wear characteristics of glazed porcelain. The authors recommended that any adjusted porcelain restoration should be re-glazed or subjected to a finishing sequence which is followed through to a final stage of polishing with a diamond paste.

Derand P et al (1999)[15] performed an in vitro investigation to rank a number of dental porcelains with respect to their wear-resistance properties. The surface hardness and surface roughness were also considered. Results obtained showed that the resistance of wear was lowest for Finesse porcelain, and highest for Creation porcelain. Surface hardness values of the porcelain were quite similar for all porcelains but could be classified into 3 groups with Finesses and Vita Alpha porcelains as the softest and Creation porcelain as the hardest material. The low-fusing porcelain Finesse showed less abrasion resistance in comparison with Ducera Gold and Ti-Ceram porcelains.

Pascal Magne et al (1999)[40] conducted this in vitro study to compare the wear of enamel against 3 types of ceramics with high esthetic potential. Laboratory finishing (glazing/polishing) and chairside polishing with a Dialite kit were simulated to compare their respective effects on wear. Quantitative changes were measured in terms of depth and volume of wear. Qualitative wear characteristics were assessed by SEM. Duceram-LFC generated increased volume loss of enamel compared with Creation and Vitadur α. Creation exhibited the lowest ceramic wear and lowest combined volume loss compared with

Duceram-LFC and Vitadur α. The most significant differences among materials were observed in volume loss, not in depth of wear. For all 3 ceramic systems, qualitative SEM evaluation revealed an abrasive type of wear. Duceram-LFC was the most abrasive ceramic for the antagonistic. Creation ceramic was the least abrasive material and most resistant to wear. Laboratory and chairside finishing procedures generated similar results.

Kawai K et al (2000)[28] compared the amount of adhesion of plaque components (bacterial cells and glucans) on the porcelain disks with various degrees of surface roughness to assess the effects of surface roughness on the amount of plaque accumulation. The amount of cells and glucans adhered on porcelain increased with incubation time. The surface roughness value and the amount of plaque adhesion decreased with the increase in polishing level. However, the greatest amount of plaque was adhered on glazed surfaces, although their surfaces were smoother than the surfaces polished with 120-or 600-grit abrasive papers. With the exception of glazed surfaces, a positive correlation between surface roughness and the amount of plaque accumulation was observed. Repolishing with a diamond paste would not induce problems of plaque accumulation, compared with an intact glazed surface.

Jordi Martinez G et al (2003)[27] compared the effect of four finishing systems and diamond paste on ceramic roughness. The initial roughness of all the samples was increased with a diamond point. The four finishing systems used were white silicon and black rubber, Shofu kit, diamond burs and Sof-Lex disks. Then all the samples were polished using Yeti diamond paste for 30 seconds. Study proved that all the four methods reduced the average roughness of the samples. The most effective system was the Sof-Lex disks. The Yeti diamond polishing paste reduced the height of the maximum peaks of the surface, but it did not improve the average roughness.

Alkhiary Y M et al (2003)[2] evaluated by means of indentation technique the effects of acid hydrolysis and mechanical polishing on the surface residual stresses of low-fusing ceramic materials. Scanning electron microscopy (SEM) was used to study surface texture before and after hydrolysis and polishing. SEM showed obvious surface flaws as a result of hydrolysis on Duceram-LFC Enamel and Dentin specimens. When comparing polished groups and non-polished groups the mean crack lengths were significantly shorter for the polished specimens of Duceram-LFC Enamel, Finesse Enamel, and Finesse Dentin porcelains compared with there control groups respectively. Hydrolysis did not improve surface residual stresses of Duceram-LFC and Finesse ceramic materials. Mechanical polishing improved surface residual stresses of all materials tested, except Duceram-LFC Dentin porcelain.

Clelland N L et al (2003)[14] evaluated the wear of human enamel opposing 5 low-fusing dental porcelains and a traditional feldspathic control. The effect of ceramic over firing on enamel wear was also evaluated. Scanning electron micrographs were made using representative ceramic samples from each group. The results indicate that none of the low-fusing ceramics resulted in significantly less wear than the VMK control. In fact, 3 of the low-fusing porcelains (OM, RP, LFC) resulted in significantly greater enamel wear than VMK. There was significantly less enamel wear opposite DS than LFC. Enamel wear was not significantly affected by the increased firing temperature. This work suggests that variations in ceramic composition and microstructure may affect the opposing enamel wear, but that low-fusing temperatures do not necessarily guarantee low enamel wear.

Camacho G B et al (2006)[10] evaluated the efficiency of different vehicles associated with diamond pastes indicated for dental ceramic polishing. Surface roughness means (Ra) of the ceramic specimens were determined with a rugosimeter. It was concluded that: 1) Robinson bristle brush, felt wheel and buff disc were efficient vehicles to be used in association with a diamond polishing paste; 2) The use of rubber cup as a vehicle showed poor efficiency for mechanical polishing of the ceramic surfaces; 3) Both pastes provided similar and efficient polishing and may be recommended for use with an appropriated vehicle.

Sarac D et al (2006)[45] conducted this in vitro study was to compare the effect of different porcelain polishing methods on the color and surface texture of a feldspathic ceramic. Quantitatively the surface roughness (Ra) (µm) of the specimens was evaluated using a profilometer. To evaluate the effects of the polishing systems on the ceramic surfaces at a microscopic level, specimens were examined under a scanning electron microscope (SEM). Results showed that the polishing techniques significantly affected the color of the feldspathic ceramic. All specimens polished with the various techniques showed significantly different Ra values than the control specimens, except for the groups polished using the adjustment kit. The highest Ra and DeltaE values were obtained with the use of polishing paste and polishing stick alone. The SEM observations demonstrated that the polishing techniques affected the smoothness of the porcelain surface. The authors concluded that the use of an adjustment kit alone or preceding polishing paste or polishing stick application created surfaces as smooth as glazed specimens. The use of polishing paste alone did not improve the smoothness of the porcelain surface.

Jarvis J et al (2006)[24] conducted this study to evaluate the alteration in surface characteristics after orthodontic debonding of two types of porcelain systems commonly used in prosthetic dentistry. Surface roughness, color, and gloss were evaluated using profilometry, color shade index, and gloss study. Bonding and debonding increased all roughness parameters tested; however, no change was revealed between the two polishing protocols. Similarly, gloss and color index changes were significantly altered after grinding, regardless of the polishing method used. No difference was identified between the two porcelain types with respect to roughness, color index, or gloss. Orthodontic bonding alters the porcelain surfaces, and postdebond polishing does not restore the surface to the prebond state.

Olivera A B et al (2006)[37] compared the effect of glazed and polished dental ceramic on the wear of human enamel. Fine ceramics were tested under standard load after 150,000 and 300,000 simulated chewing cycles. Wear was determined from collected digital data and analyzed before and after loading. Statistical comparisons were analyzed. Polished ceramics produced less enamel wear. The amount of enamel wear for opposing IPS Empress Ceramic was significantly higher ($P < .001$) than wear provoked by the other ceramics. The enamel wear rate was higher at the first 150,000 cycles, and polishing increased ceramic roughness, except for the IPS Empress ceramic. Polishing of dental ceramics at the contact area produces less antagonistic enamel wear.

Sarac S et al (2007)[46] did to compare the surface roughness produced by three polishing techniques by polishing 2 all-ceramic materials after surface conditioning. Air particle abrasions (APA) with 25-μm aluminum trioxide, 9.6% hydrofluoric acid (HFA), and APA + HFA were applied for ceramic surface conditioning. Subsequently, the ceramics were subjected to 3 polishing techniques: polishing kit, polishing paste, and polishing kit + polishing paste. Surface roughness (Ra) was evaluated profilometrically. The highest ΔRa values were obtained with the polishing kit and polishing kit + paste for the APA + HFA groups. No significant differences were observed among the polishing paste groups. Combining a polishing kit and polishing paste produced the smoothest ceramic surfaces.

Jefferies S R (2007)[26] in this article provides a clinically useful, outcome-supported discussion of existing and well-known products, and also provides a glimpse into new and emerging concepts in optimal surface finishing, polishing, and surface maintenance in restorative dentistry. The primary goal of finishing and polishing technology and procedures in dental restorative procedures is to create restorations that are aesthetically natural and harmonize both in function and appearance with the surrounding natural tooth structure. Highly effective and efficient finishing and polishing procedures achieve this objective by producing restorations with a surface smoothness and light reflectivity similar to natural tooth structure. Optimal surface properties and smoothness are also important for maintaining the tooth-restorative interface-appropriate oral hygiene procedures.

MATERIALS AND METHOD

This study was conducted to investigate in vitro, the effect of two ceramic finishing systems and diamond polishing paste had on the surface texture of two ceramic materials used for ceramo-metal restorations:

The following materials were used for the study:

- Metallic mold for obtaining standardized test specimens (Custom – made) (Fig.1,2)
- Pattern resin, Acrylic resin for patterns (GC Corporation, Tokyo, JAPAN) (Fig.3)
- White petroleum jelly (Tejpa & co, INDIA)
- Sprue wax, 2.5mm and 3.5mm diameter (Bego, GERMANY) (Fig.4a)
- Surfactant spray (Silikon & waches entspanner, GERMANY) (Fig.4b)
- Ring liner (Flex Vest liner, Ivoclar Vivadent, GERMANY) (Fig.4c)
- Crucible former (Whip Mix, USA) (Fig.4d)
- Alloy casting rings of 4cm diameter and 5cm length (Whip Mix, USA) (Fig.4e)
- Phosphate bonded Investment (MOLDAVEST exact, Heraeus Kulzer GmbH, GERMANY) (Fig.4f)
- Investment BS Liquid 1 (Colloidal silica, Heraeus Kulzer GmbH, Germany) (Fig.4g)
- Base metal nickel chromium alloy (HERAENIUM-S, Heraeus Kulzer GmbH, GERMANY) (Fig.4h)
- Aluminum oxide powder for sandblasting (Delta, INDIA)
- Separating Discs (Dantaurum, New York,USA) (Fig.4i)

- **Metal – Ceramic systems employed in the study :**

a. Feldspathic porcelain (Ivoclar-IPS Classic, Ivoclar Vivadent AG, Liechtenstein, GERMANY), D3, shade (Fig.5a)
b. Fluorapatite leucite porcelain (Ivoclar-d sign, Ivoclar Vivadent AG, Liechtenstein, GERMANY), D3, shade (Fig.5b)

- Ceramic Slab (Vita, Bad Sackingen, GERMANY) (Fig.6a)
- Ceramic Holder (Ivoclar Vivadent Ag, Liechtenstein, GERMANY) (Fig.6b)
- Ceramic Honeycomb tray (vita, Bad Sackingen, GERMANY) (Fig.6c)
- Ceramic Brushes (Ivoclar Vivadent AG, Liechtenstein, GERMANY) (Fig.6d)
- Tissues (Premier Aryco, INDIA) (Fig.6e)
- Sintered Diamond (Diatech Dental AG, Heerbrugg, Switzerland) (Fig.7)
- Sof-Lex discs: coarse, medium, fine and extrafine (3M ESPE, Dental Products Division, St.Paul, MN) (Fig.8a)
- White silicon and grey rubber (Dentsply/Caulk, Milford, U.S.A) (Fig.8b)
- Diamond polishing paste (YETI Dental Products, GmbH, GERMANY) (Fig.9)
- Rubber prophy cup (Webbed Latch; DentAmerica Ind, Bedford Circle, CA, U.S.A) (Fig.9)

The following equipments were used for the study:

Laboratory equipments:

- Vacuum power mixer (The Continental, Whip Mix, Kentucky, USA)
- Burn-out furnace (Technico, Technico laboratory products PVT, LTD. Chennai, INDIA.
- Induction casting machine (Fornax GEU, Bego, GERMANY)

- Sand blaster (Basic Professional, Renfert GmbH, GERMANY)
- Alloy grinder (Demco, Dental Maintenance Co., INC, California, USA)
- Dental porcelain furnace – Vita Vacument 100 (vita, Bad Sackingen, GERMANY) (Fig.10)
- Micromotor (Micromotor Strong series Saeshin precision Find. co, KOREA)
- Physical Balance (Mettler Toledo Weighing Machine, Ohio, USA)

Testing equipments:

- Scanning Electron Microscope (JEOL, ASM 6360, JAPAN) (Fig.11)
- Profilometer (Taylor Hobson, Talysurf, UK) (Fig.12)

Scanning Electron Microscopy (SEM) for surface texture analysis:

In the present study the surface texture of the ceramic test specimens was analyzed qualitatively using the Scanning Electron Microscope (JEOL, ASM 6360, Japan Electronic). (fig.11)

Electron microscopes use a beam of highly energetic electrons (1keV- 1MeV) to examine objects on a very fine scale (0.2 nm upwards). They can reveal the fine structure of a variety of materials. As the name suggests, SEM uses a scanned beam rather than a fixed beam. It is used primarily for the examination of thick (i.e. electron opaque) samples. The specimens to be magnified may have some conductivity and may get charged up. So they are coated with a platinum layer to prevent the charging up and in order to increase the secondary emissions. Sometimes the specimens may be coated with tungsten with tungsten when a higher magnification is essential.

The incident electron probe scans the sample surface and the signals produced are used to modulate the intensity of a synchronously scanned beam on a CRT screen. The electron which are back scattered from the specimen are collected to provide (i) topographical information (i.e. detailed shape of the specimen surface) if low energy secondary electrons ($\leq$ 50 eV) are collected; (ii) atomic number and reorientation information if the higher energy, back scattered electrons are used, or if the leakage current to the earth is used. The magnification is given immediately by the ratio of the CRT scan size to the specimen scan size.

Profilometry for surface texture analysis:

In the present study the surface texture of the ceramic test specimens was analyzed quantitatively using the Profilometer (Taylor Hobson, Talysurf, UK) (FIG.12).

Profilometer is a contact stylus instrument used to measure surface textures (profiles, roughness) with a resolution (Z) of 16nm/1mm. A two axis laser interferometric transducer coupled to a pivoted stylus is used to precisely measure both vertical and horizontal data of a surface using ultra software.

A diamond stylus (2-µm tip radius) was used under a constant measuring force of 4mN to measure the Ra value. The instrument was calibrated using a standard reference specimen, then set to travel at a speed of 0.5mm/sec for traveling length of 0.1 to 50 mm during testing. A mean roughness profile (Ra) was determined of each specimen to describe the overall roughness of the surface.

Description of custom – made Metallic mold:

The present study was conducted with test specimens having a metal substructure overlaid with porcelain. To obtain standardized test specimens, a custom metallic mold (fig.1, 2) was fabricated to the dimensions as required by the testing equipment employed in this study. The custom metallic mold is a three piece unit consisting of [a] Base (fig.1a) [b] Middle flat plate (fig.1b) [c] Lid (fig.1c) made up of stainless steel. Four rivets are present at the corners of the base and corresponding holes are present in the middle plate and upper lid to aid in seating these two parts over the base precisely. The middle flat plate of the unit has a thickness of 2 mm (fig.2). Five square slots, each measuring 10x10mm were cut out in the middle flat plate. When the middle flat plate was seated onto the base, five equal dimension slots were formed, to obtain resin patterns (fig.14). The five slots each measuring 10mm in length and 10mm in width and 2mm in thickness were separated by and equal distance of 7mm (fig.2). Patterns of standardized dimensions were prepared using this custom mold. These were subsequently cast to obtain the metal substructure of all the test specimens for each test group.

METHODOLOGY

The methodology adopted for this study has been divided into the following stages:

I. Preparation of the porcelain fused to metal test samples:

a. Pattern fabrication
b. Casting and finishing of metal substructure of test specimens
c. Veneering of the metal substructure with the test porcelain systems:
    i. Veneering with Feldspathic porcelain
    ii. Veneering with Fluorapatite leucite porcelain

II. Surface texture evaluation of the Autoglazed test samples qualitatively and quantitatively.

III. Surface texture evaluation of the Autoglazed test samples following abrasion and finishing with two different ceramic finishing systems (Sof-Lex discs and White silicon and grey rubber) qualitatively and quantitatively.

GROUP I: Feldspathic porcelain (20 samples)

SUBGROUP-IA, finished with Sof-Lex discs (coarse, medium, fine, extra fine)

SUBGROUP-IB, finished with White silicon & grey rubber.

GROUP II: Fluorapatite leucite porcelain (20 samples)

SUBGROUP-IIA, finished with Sof-Lex discs (coarse, medium, fine, extra fine)

SUBGROUP-IIB, finished with White silicon & grey rubber.

IV. Surface texture evaluation of the finished test samples after polishing with diamond polishing paste qualitatively and quantitatively.

I. Preparation of the porcelain fused to metal test samples:

a. Pattern fabrication:

The custom – made metallic mold (Fig.1, 2) as described previously, was used to fabricate standardized resin patterns. A thin coat of whit petroleum jelly (Tejpa & co, INDIA) was applied over all the components of the metal mold on all sides. The middle plate was placed on the base and auto polymerizing pattern resin was mixed and poured into the slots. The upper lid of the metallic mold was placed into the rivets over the resin and was precisely closed using a bench press (Fig.13). After the pattern resin set, the upper lid was removed and thus plastic resin patterns were obtained. The dimensions of the patterns were 10mm width and 2mm thickness. In this manner a total of forty resin patterns were fabricated to provide twenty specimens for each test porcelain system employed in the study.

b. Casting and finishing of metal substructure of test specimens:

All the forty patterns were sprued with preformed wax sprue (Bego, GERMANY) (Fig.4a) of 2.5 cm lengths and 2.5 mm diameter and invested using phosphate bonded investment (MOLDAVEST exact, Heraeus Kulzer GmbH, GERMANY) (Fig.4f) mechanically mixed with colloidal silica (investment BS Liquid 1 – Heraeus Kulzer) (Fig.4g) according to the manufacture's instructions under vacuum using vacuum power mixer (Whip Mix. Inc. Co. U.S.A.) After a 20 minute bench set time the patterns were subsequently burnt out in a burnout furnace (Technico, Technico laboratory products pvt. Ltd., Chennai, India.) and cast using nickel chromium alloy (Heraenium S – Heraeus Kulzer) (Fig.4h) in an induction casting machine (Fornax GEU, Bego, GERMANY) followed by divesting and finishing the casting to obtain test specimens of uniform dimensions of 10x10x2mm. The dimension of each test specimen was verified by measuring the length and breadth using a stainless steel ruler and the thickness with an Iwanson's gauge. (Essago, GERMANY) (Fig.17). The acceptable specimens were then air abraded and subsequently steam cleaned to remove surface impurities. In this manner a total of forty metal substructures of standardized dimensions were obtained. These were randomly assigned into two main groups (Group I & Group II) with twenty samples in each test group. Group I & Group II samples were subsequently veneered with feldspathic porcelain and fluorapatite leucite porcelain systems respectively.

c. Veneering the metal substructure with test porcelain: In this study, ***Feldspathic porcelain*** (Ivoclar-IPS Classic, Ivoclar Vivadent AG, Liechtenstein, GERMANY) and ***Fluorapatite leucite porcelain*** (Ivoclar- d sign, Ivoclar Vivadent AG, Liechtenstein, GERMANY) employed were assigned as group I and II respectively. A common basic D3 shade was selected for both the porcelain systems. All the test specimens were fired in Dental porcelain furnace – Vita Vacumat 100 (Vita, Bad Sackingen, GERMANY) (Fig.10)

i) Veneering with Feldspathic porcelain:

On the group I comprising of twenty specimens opaque of the chosen D3 shade was painted onto the prepared metal substructure. The wash opaque was fired in Dental porcelain furnace-Vita Vacumat 10 (Vita, Bad Sackingen, GERMANY) (Fig.10) according to manufacturer's instructions given in table 1 (Fig.21a) and a second layer of opaque was applied to completely mask the metal. The second firing was done as per the chart given in table 1. The thickness of opaque layer was between 0.3 – 0.4mm after two firings (Fig.20a) for all specimens. This was followed by the application of dentine porcelain of D3 shade on the opaque layer excess liquid on the surface was absorbed using tissue paper (Premier Aryco, INDIA) (Fig.10e) and was fired according to manufacturer's instruction given in table 1. The thicknesses of samples were adjusted with mounted stones to achieve a thickness of 0.7mm of dentine porcelain (Fig.20b). This was followed by the application of enamel porcelain and firing according to manufacturer's instructions given in table 1. The specimens were ground to obtain an even thickness of 0.5mm of enamel porcelain (Fig.20c). Total thickness of the sample after veneering the test porcelain was 3.5mm (2mm metal +0 .3mm opaque + 0.7mm dentine + 0.5mm enamel (Fig.21).

Table 1: Firing Schedule for Feldspathic Porcelain Specimens

Procedure	T Max (ºC)	Preheat (min)	Heat Up Rate(mins)	Peak Temp (mins)	Vacuum Time (mins)
I Opaque	980	4	6	1	6
II Opaque	970	4	6	1	6
I/II Body	920 /920	4	8/9	1	8/9
Auto Glaze	900/920	4	8/9	1	8/9

ii) Veneering with Fluorapatite leucite porcelain

The twenty specimens of group II were veneered with D3 shade of Fluorapatite leucite porcelain (Ivoclar- d sign) in a similar manner as done in group I difference being the firing temperature as given by the manufacturer in table 2.

Table 2: Firing schedule for Fluorapatite Leucite Porcelain Specimens

Procedure	T Max (ºC)	Preheat (mins)	Heat Up Rate(mins)	Peak Temp (mins)	Vacuum Time(mins)
I Opaque	900	6	6	1	6
II Opaque	890	6	6	1	6

I/II Dentine	870	4-9	8	1	8
Auto Glaze	870	4	8	0.5-1	8

For both group I and group II test samples, the chosen ceramic thickness was 1.5mm. To achieve this uniformity, the samples were measured at multiple points using metal caliper. The excess was adjusted with diamond points and then the two groups of ceramic plates were autoglazed according to the manufacture's instructions and subjected to surface texture analysis. In this study, Autoglazed samples are used as control group.

II. Surface texture evaluation of the Autoglazed test samples qualitatively and quantitatively.

All the specimens of both the test groups were qualitatively analyzed using scanning Electron Microscope (JEOL, ASM 6360, JAPAN) (Fig.11) and photomicrographs were obtained 1000x magnification. The basic working principle of the Scanning Electron Microscope has been described previously at the beginning of this section. The specimens were coated with a platinum layer and the incident electron probe scanned the sample surface. The electrons which were back scattered from the specimen are collected to provide topographical information on the surface texture of autoglazed specimens.

All the specimens of both the test groups were quantitatively analyzed using profilometer (Taylor Hobson, Talysurf, UK) (Fig.12) to determine a surface roughness profile of each specimen. A mean surface roughness profile (Ra) was determined to describe the overall roughness of the surface. In this manner qualitative and quantitative analysis of surface texture was done and the initial sets of values were obtained.

III. Surface texture evaluation of the Autoglazed test samples following abrasion and finishing with two different ceramic finishing systems (Sof-Lex discs and White silicon and grey rubber) qualitatively and quantitatively.

Total of forty Autoglazed Test samples were abraded with a medium-grit sintered diamond rotary cutting instrument (Diatech Dental AG, Heerbrugg, Switzerland) (Fig.7) with a slow-speed hand piece, rotating at approximately 10,000 rpm in a unidirectional motion with water cooling to simulate the surface conditions after an intraoral adjustments. Following abrasion, Total of forty test samples were divided into GrI and GrII as follows:

GROUP I: Feldspathic porcelain (20 samples)

SUBGROUP-IA, finished with Sof-Lex discs (coarse, medium, fine, extra fine)

SUBGROUP- IB, finished with White silicon & grey rubber.

GROUP II: Fluorapatite leucite porcelain (20 samples)

SUBGROUP-IIA, finished with Sof-Lex discs (coarse, medium, fine, extra fine)

SUBGROUP-IIB, finished with White silicon & grey rubber.

Sof-Lex discs are coated abrasives used for finishing ceramic materials. The abrasive particles are retained on the surface of the disc material or matrix by an adhesive polymeric surface coating.

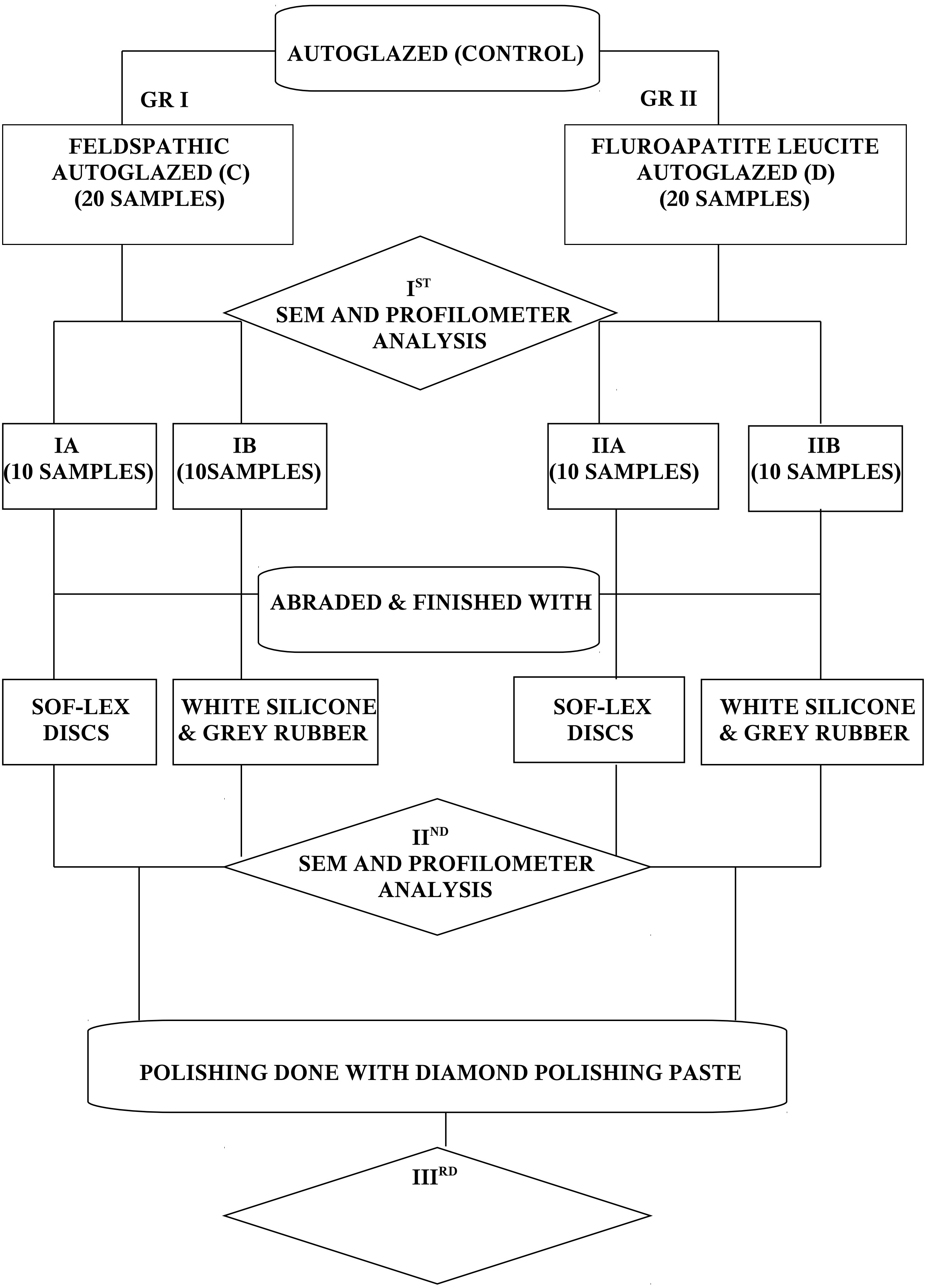
White silicon & grey rubber are bonded abrasives used for finishing ceramic materials. The abrasive particles are uniformly dispersed through out the elastomeric matrix such as a rubber or silicon compound.

Following abrasion with sintered diamond, out of 20 specimens of Gr I (Feldspathic), 10 test specimens were finished with Sof-Lex discs and designated as subgroup IA, and 10 specimens with White silicon and grey rubber and designated as IB. Similarly, for the GrII (Fluorapatite leucite), 10 specimens of subgroup IIA were finished with Sof-Lex discs and 10 specimens of subgroup IIB with White silicon and grey rubber, following abrasion with sintered diamond. All the test specimens were subjected to qualitative and quantitative surface texture analysis using scanning electron microscope and profilometer respectively and the second set of values were obtained.

IV Surface texture evaluation of the finished test samples after polishing with Yeti diamond paste qualitatively and quantitatively.

Diamond polishing pastes contain loose abrasive diamond particles in particle size ranges less than 10µ. These pastes are primarily indicated for final polishing of adjusted ceramic materials.

All the specimens of both the test group were polished by Yeti diamond paste (Yeti diamond products) (Fig.9) along with rubber prophy cup for 30 seconds. Final set of values of their surfaces were obtained qualitatively with SEM and quantitatively using profilometer respectively.


AUTOGLAZED (CONTROL)
GR I
GR II
FELDSPATHIC AUTOGLAZED (C) (20 SAMPLES)
FLUROAPATITE LEUCITE AUTOGLAZED (D) (20 SAMPLES)
IST SEM AND PROFILOMETER ANALYSIS
IA (10 SAMPLES)
IB (10SAMPLES)
IIA (10 SAMPLES)
IIB (10 SAMPLES)
ABRADED & FINISHED WITH
SOF-LEX DISCS
WHITE SILICONE & GREY RUBBER
SOF-LEX DISCS
WHITE SILICONE & GREY RUBBER
IIND SEM AND PROFILOMETER ANALYSIS
POLISHING DONE WITH DIAMOND POLISHING PASTE
IIIRD

Figures

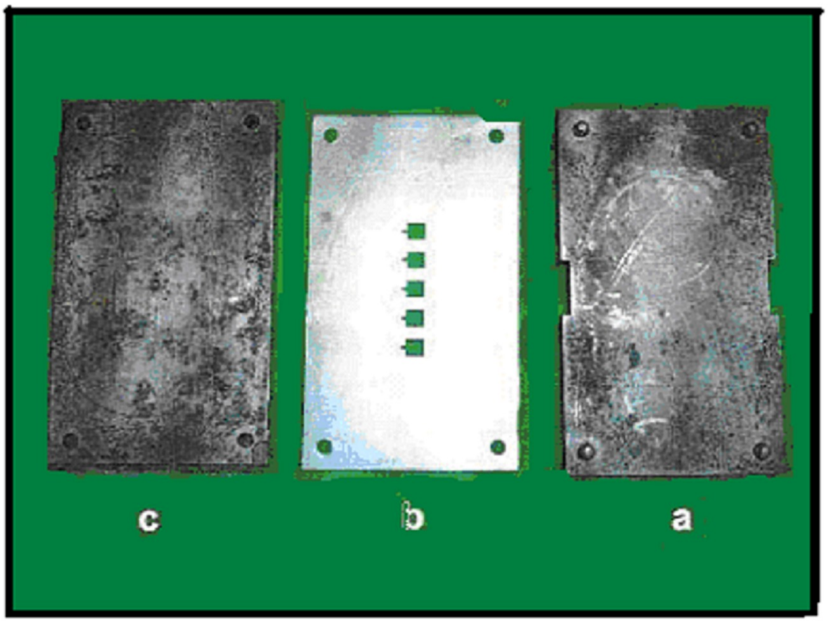


Fig.1. Custom-made Metallic mold
a. Base b. Middle flat plate c. Lid

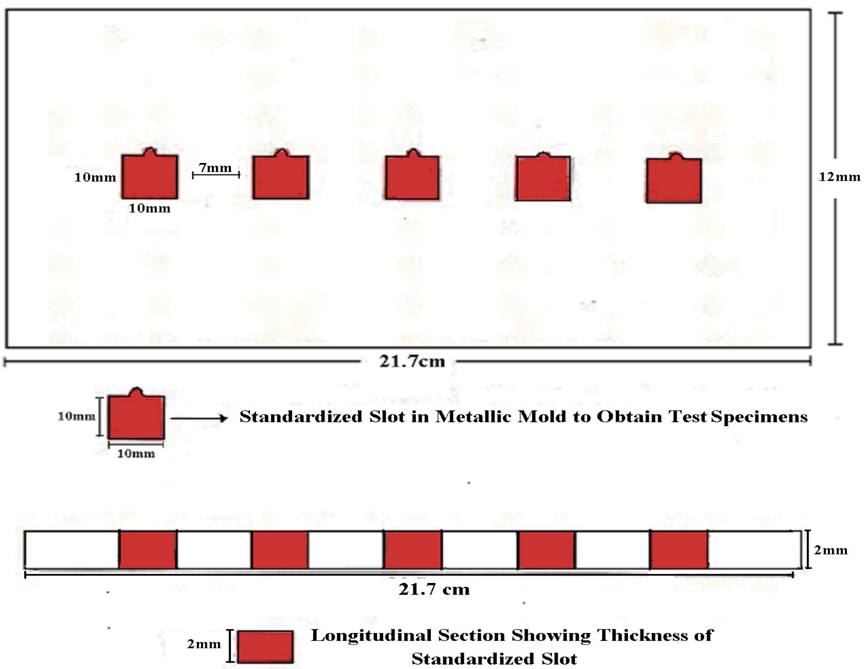
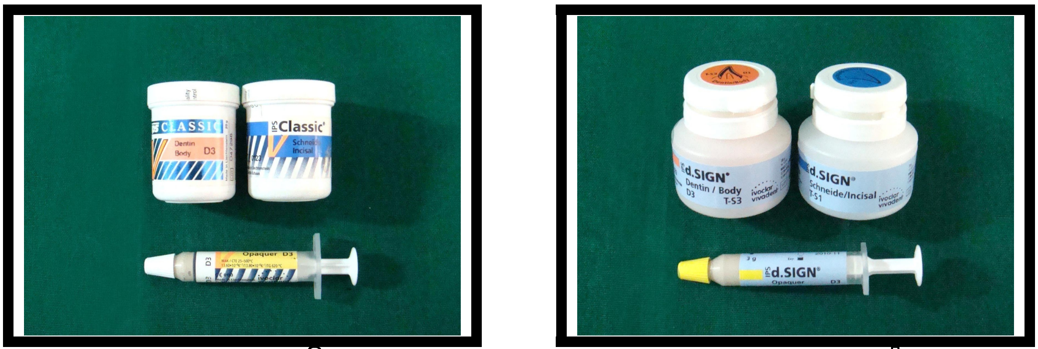


Fig.2. Schematic representation of custom metallic mold

Fig.3.Pattern resin

Fig.4. Laboratory materials required for the fabrication of metal substructure. a. Sprue wax
b. Surfactant spray c. Ring liner d. Crucible former
e. Casting ring f. Phosphate bonded Investment
g. Colloidal silica h. Nickel - Chromium alloy
i. Separating discs



a b

Fig.5. Test porcelain systems
a. Feldspathic porcelain b. Fluorapatite Leucite porcelain

Fig.6. Laboratory tools required for porcelain veneering
a. Ceramic slab b. Ceramic holder c. Ceramic honeycomb tray
d. Ceramic brushes e. Tissues

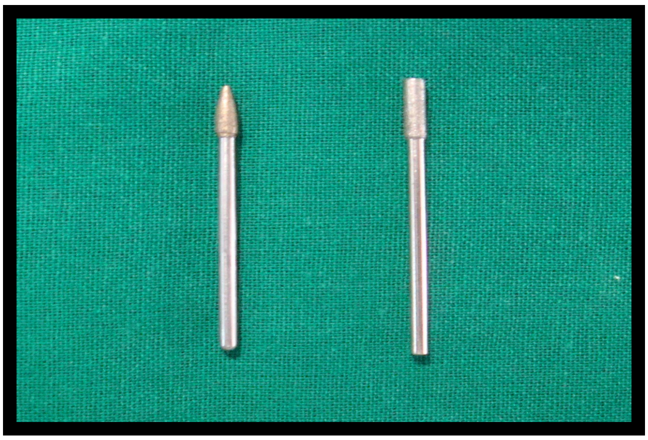


Fig.7. Sintered Diamond

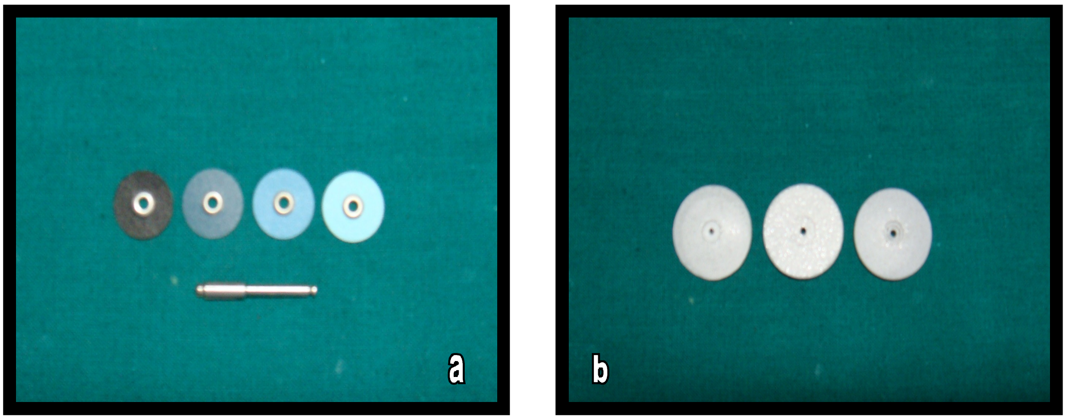


Fig.8. Porcelain Finishing systems
a. Soft-Lex discs b. White silicon and grey rubber

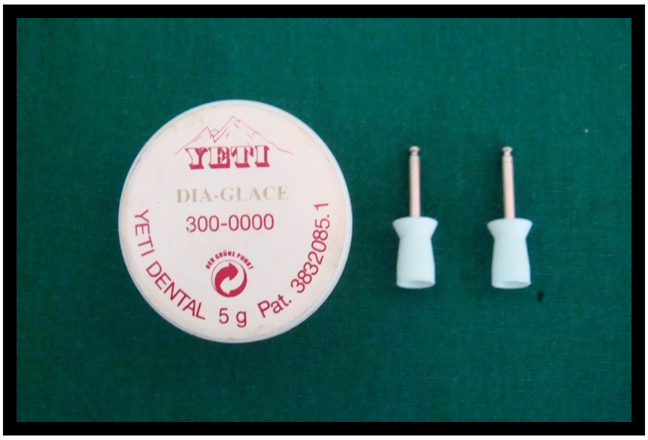


Fig.9. Diamond Polishing paste

Fig.10. Dental Porcelain Furnace

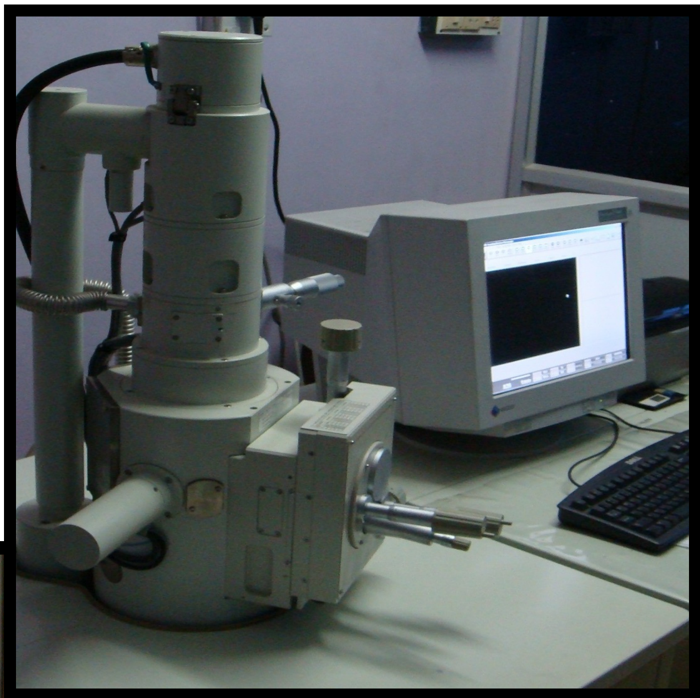


Fig.11. Scanning Electron Microscope

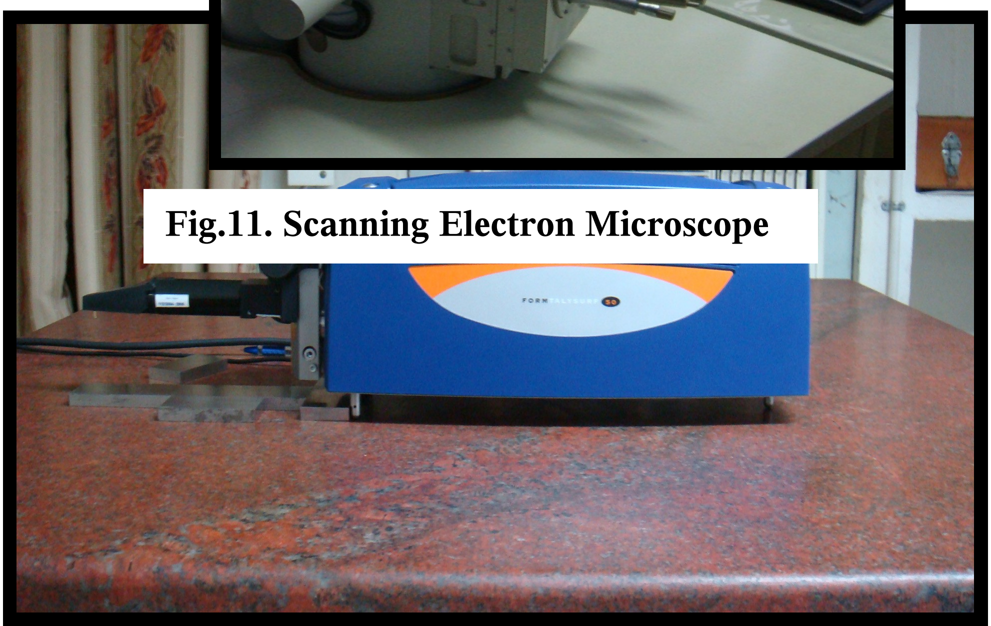


Fig.12. Profilometer

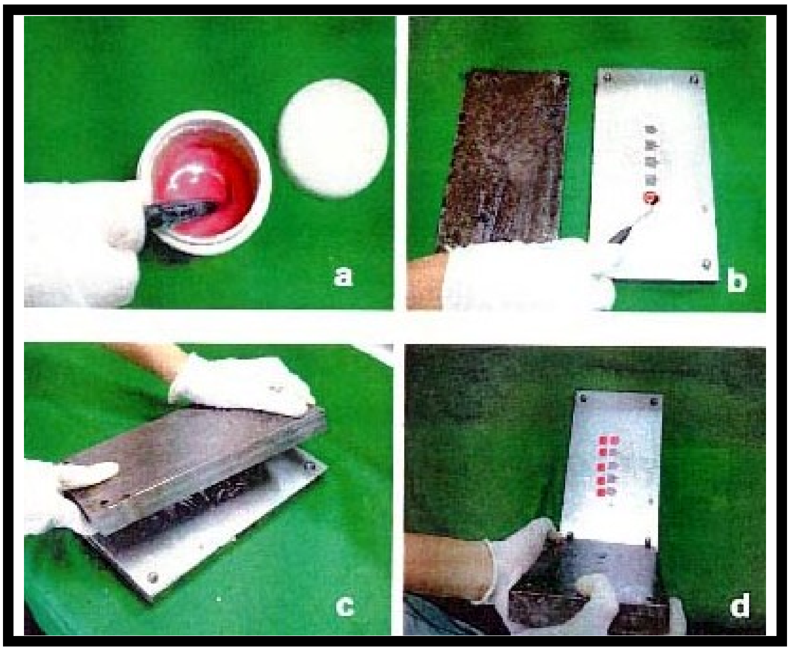


Fig.13. Fabrication of resin patterns

a. Mixing of pattern resin b. Pattern resin poured into the slots c. Closure of lid d. Removal of lid to obtain standardized resin patterns

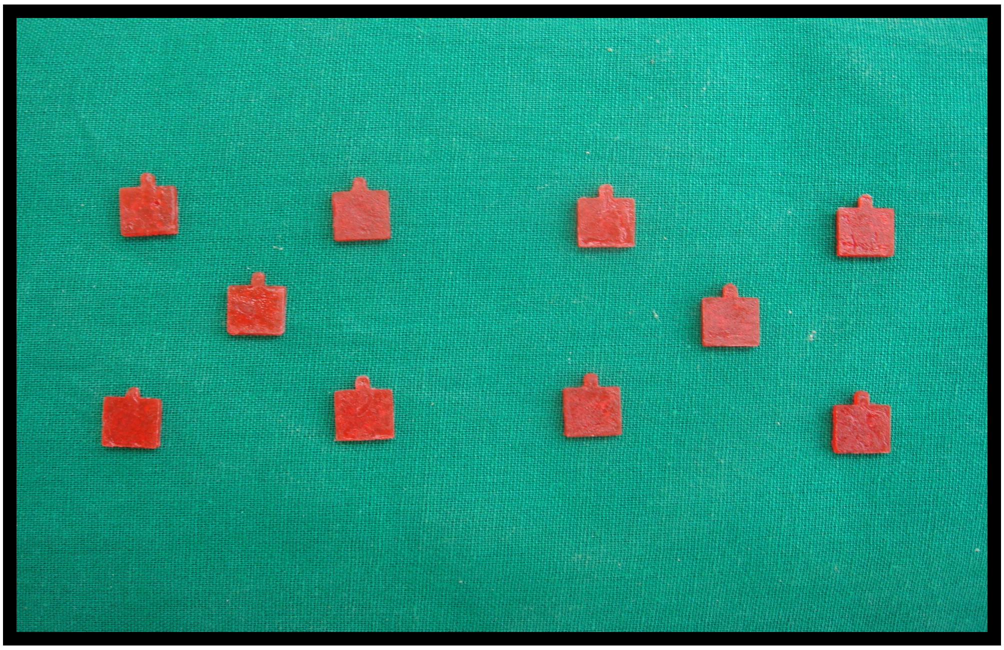


Fig.14. Standardized resin patterns

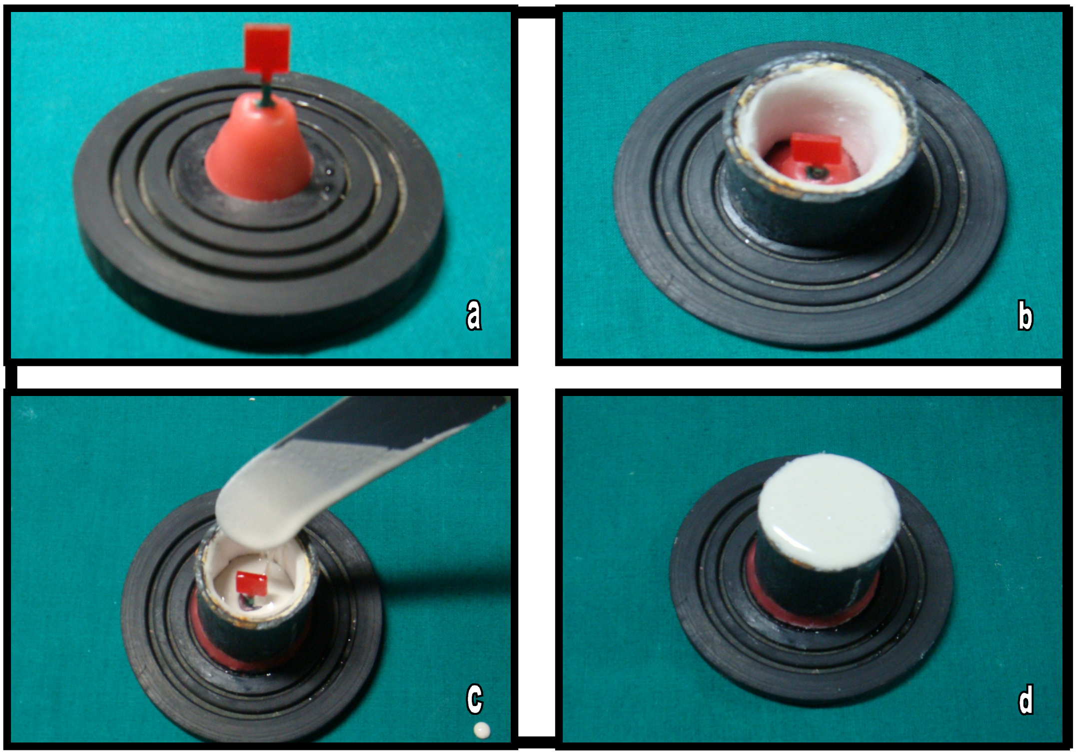


Fig.15. Casting the resin pattern
a. Pattern attached to crucible former b. Pattern positioned in the casting ring c. Investing the pattern d. Invested pattern

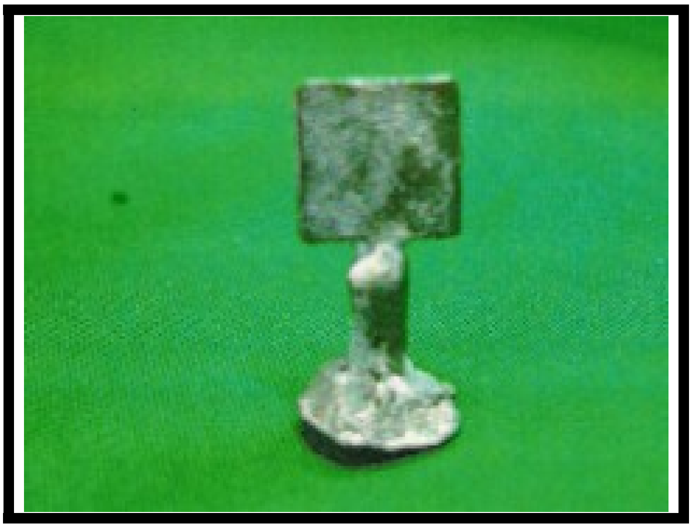


Fig.16. Divested casting

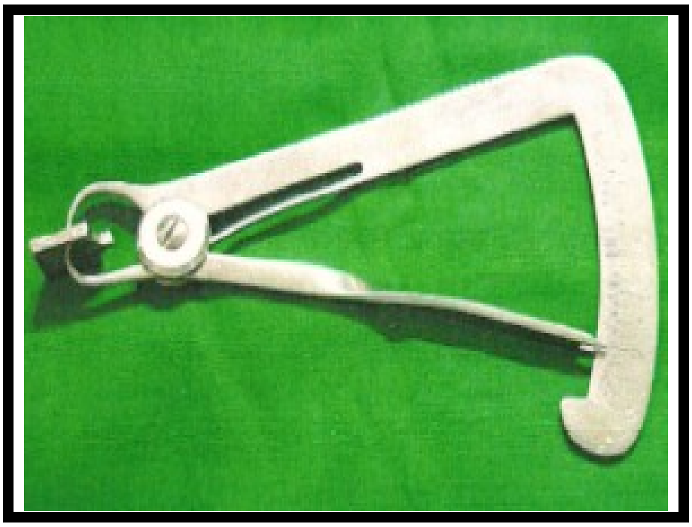


Fig .17. Thickness of finished metal substructure (2mm)

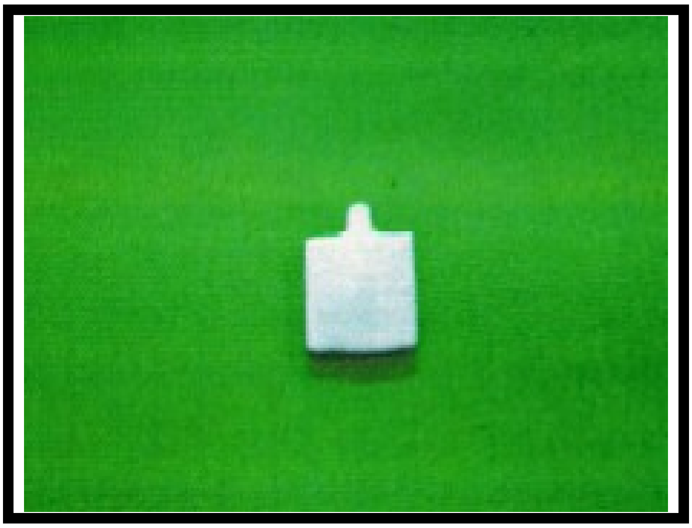


Fig.18. Sandblasted metal substructure

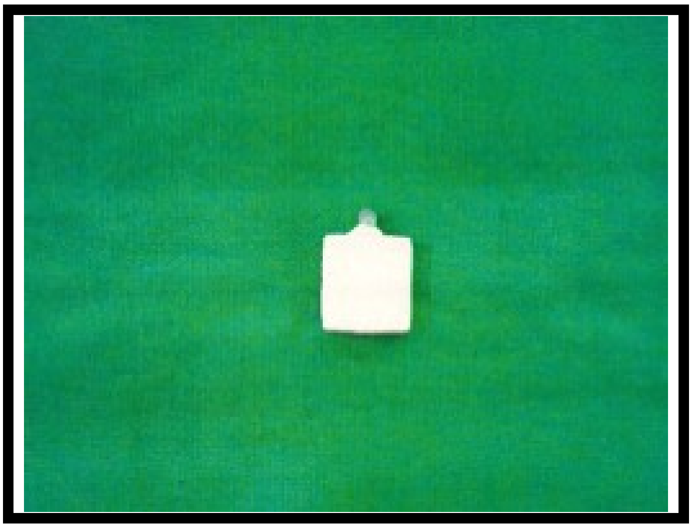


Fig.19. Metal substructure veneered with test porcelain

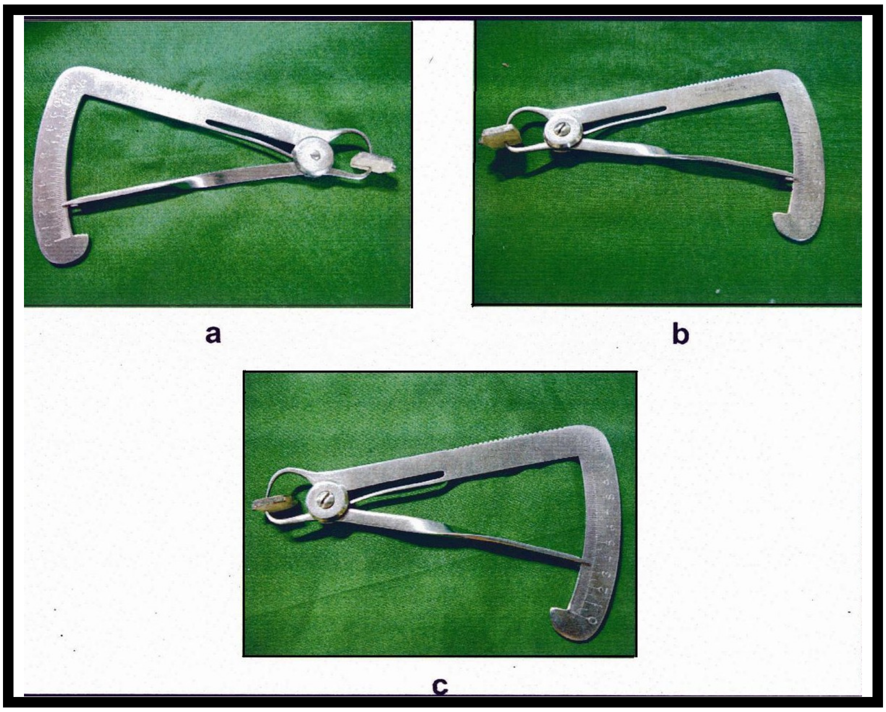


Fig.20. Thickness of test specimen after addition of different layers of Porcelain a. Opaque layer (2.3mm) b. Dentin porcelain (3mm)

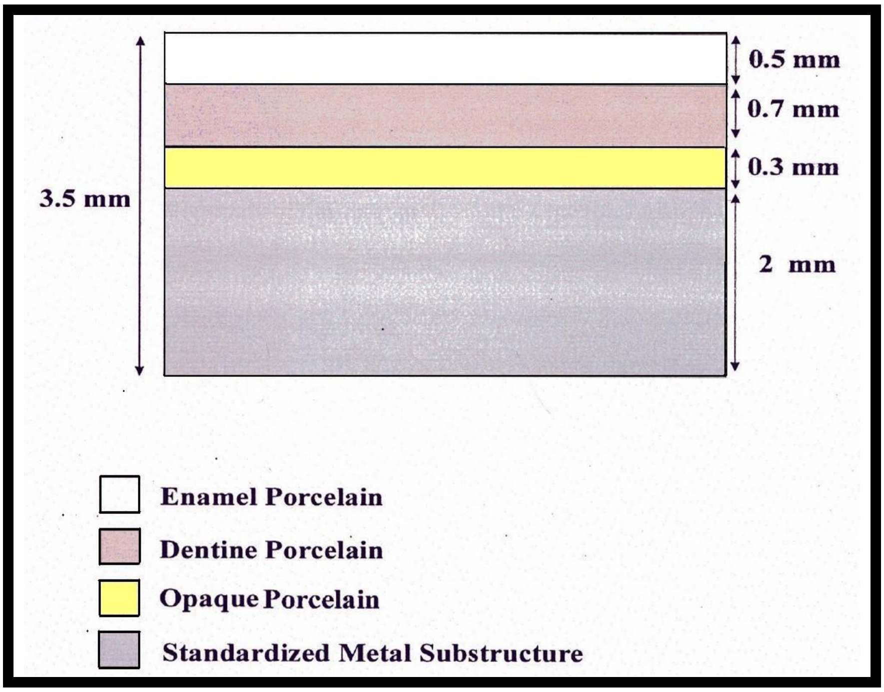


Fig.21. Schematic representation of thickness of the specimen after veneering the test porcelain

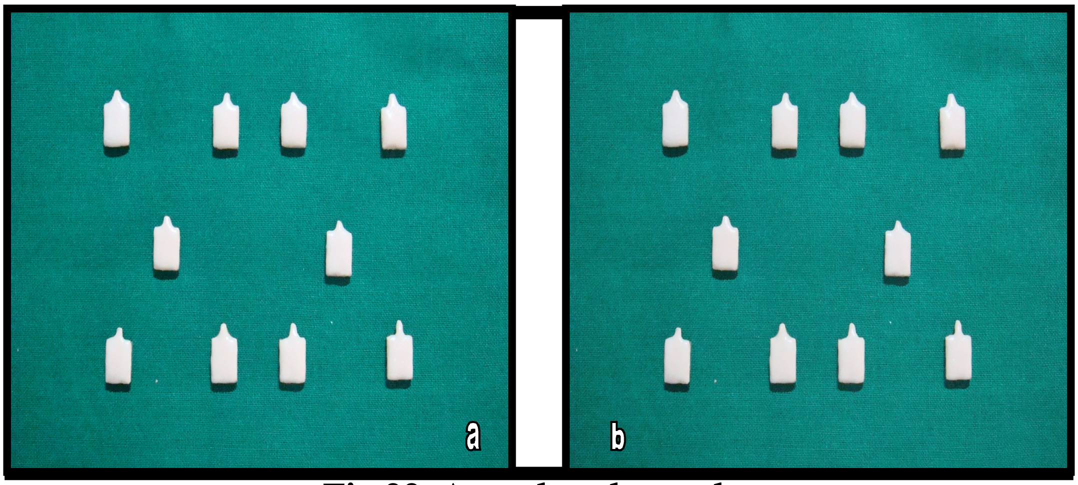
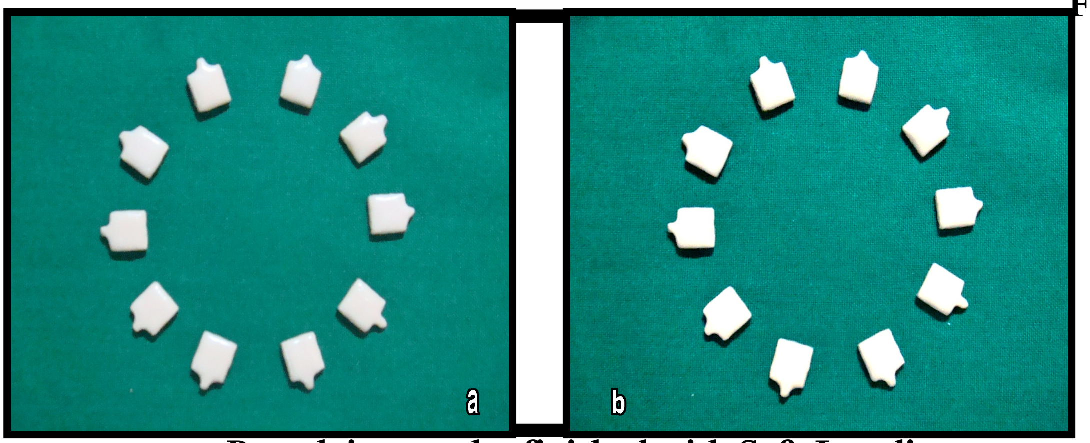


Fig.22. Autoglazed samples
a. Feldspathic porcelain b. Fluorapatite leucite porcelain

Fig.23.



Porcelain samples finished with Soft-Lex discs
a. Feldspathic porcelain b. Fluorapatite leucite porcelain

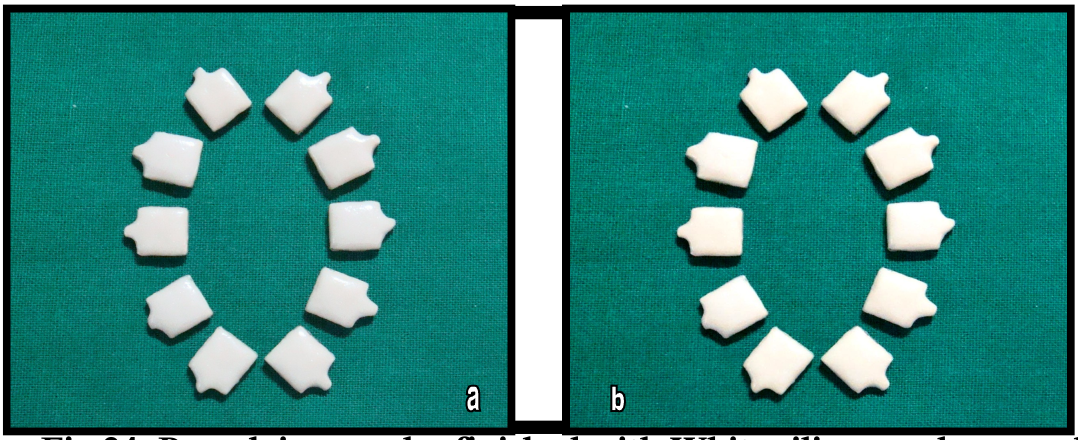


Fig.24. Porcelain samples finished with White silicon and grey rubber
a. Feldspathic porcelain b. Fluorapatite leucite porcelain

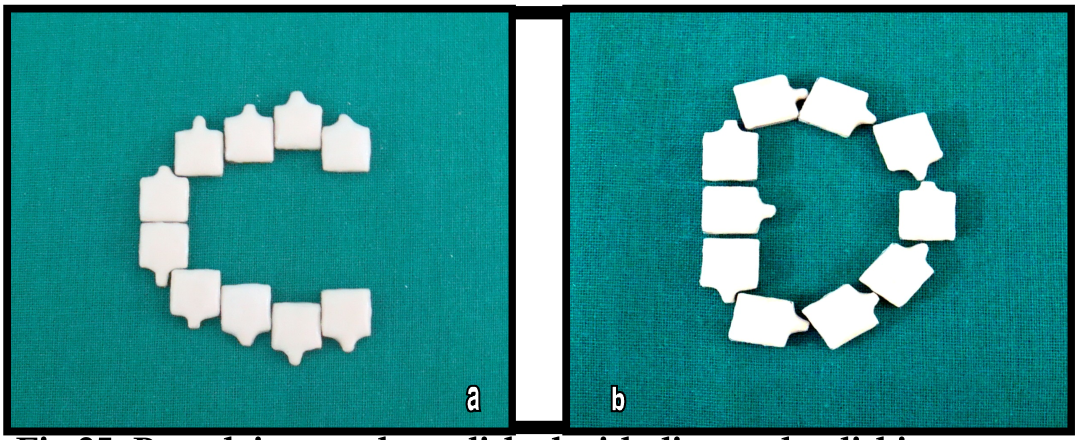


Fig.25. Porcelain samples polished with diamond polishing paste
a. Feldspathic porcelain b. Fluorapatite leucite porcela

RESULTS

The present study was designed to qualitatively and quantitatively evaluate and compare the effect of two ceramic finishing systems and diamond polishing paste had on the surface texture of two different ceramic materials used for ceramo-metal restorations. The two porcelain systems employed were Feldspathic (Group I) and Fluorapatite leucite (Group II) porcelain systems. A total of 40 specimens were prepared and 20 specimens were included in each test group as follows:

GROUP I: Feldspathic porcelain (20 samples)

SUBGROUP-IA, finished with Sof-Lex discs (coarse, medium, fine, extra fine)

SUBGROUP- IB, finished with White silicon & grey rubber.

GROUP II: Fluorapatite leucite porcelain (20 samples)

SUBGROUP-IIA, finished with Sof-Lex discs (coarse, medium, fine, extra fine)

SUBGROUP-IIB, finished with White silicon & grey rubber.

Each of these forty specimens was subjected to analysis of surface texture qualitatively and quantitatively using SEM and profilometer respectively. The data obtained was grouped as under:

GROUP I: Feldspathic porcelain system (20 samples)

- **1a**: Surface texture analysis of the autoglazed Feldspathic porcelain specimens qualitatively using SEM.
- **1b**: Surface texture analysis of Feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon and grey rubber qualitatively using SEM.

- **1c**: Surface texture analysis of Feldspathic porcelain specimens finally after polishing qualitatively using SEM.
- **1d**: Surface texture analysis of the autoglazed Feldspathic porcelain specimens quantitatively using profilometer.
- **1e**: Surface texture analysis of Feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon and grey rubber quantitatively using profilometer.
- **1f**: Surface texture analysis of Feldspathic porcelain specimens finally after polishing quantitatively using profilometer.

GROUP II: Fluorapatite leucite porcelain system (20 samples)

- **2a**: Surface texture analysis of the autoglazed Fluorapatite leucite porcelain specimens qualitatively using SEM.
- **2b**: Surface texture analysis of Fluorapatite leucite porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon and grey rubber qualitatively using SEM.
- **2c**: Surface texture analysis of Fluorapatite leucite porcelain specimens finally after polishing qualitatively using SEM.
- **2d**: Surface texture analysis of the autoglazed Fluorapatite leucite porcelain specimens quantitatively using profilometer.
- **2e**: Surface texture analysis of Fluorapatite leucite porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon and grey rubber quantitatively using profilometer.
- **2f**: Surface texture analysis of Fluorapatite leucite porcelain specimens finally after polishing quantitatively using profilometer.

I. Qualitative analysis of surface texture of the test porcelain:

Fig.26.1a: SEM Photomicrographs (1000x magnification) showing surface texture of the autoglazed feldspathic porcelain specimens.

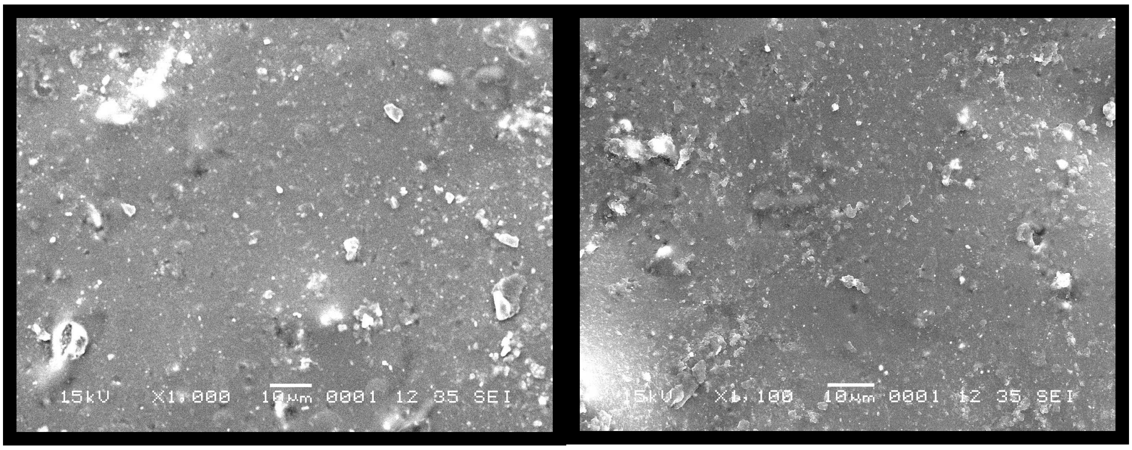
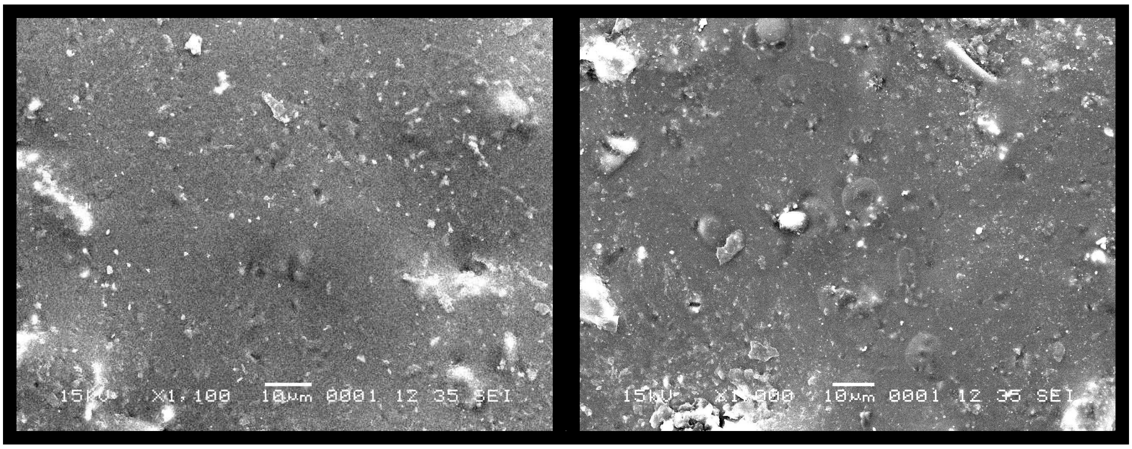


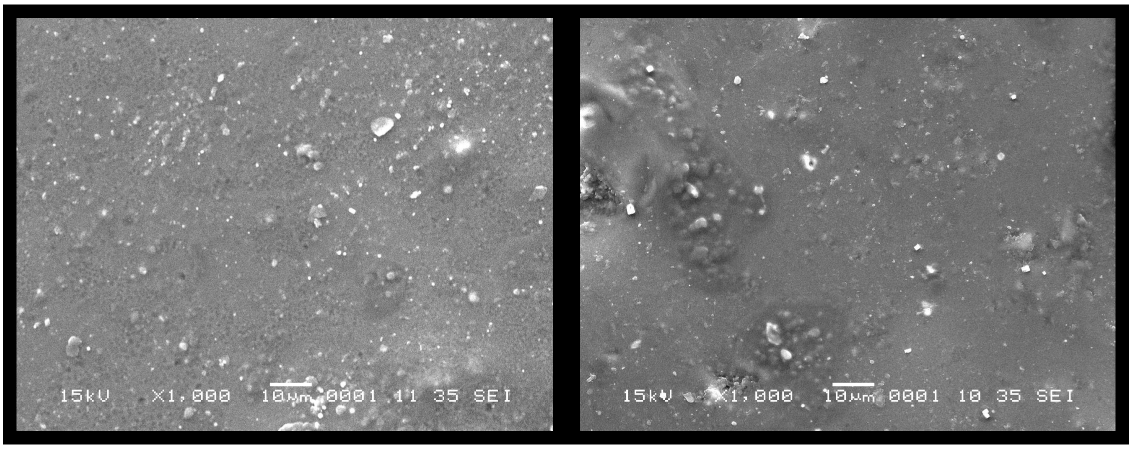
Fig.27.1b: SEM Photomicrographs (1000x magnification) showing surface texture of feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon & grey rubber.



(a)
Sof-Lex discs

(b)
White silicon & grey rubber

Fig.28.1c: SEM Photomicrographs (1000x magnification) showing surface texture of feldspathic porcelain specimens after polishing.



(a)
Sof-Lex discs

(b)
White silicon & grey rubber

Inference: Surface of feldspathic porcelain specimens at initial recording (Autoglazed samples), as observed under SEM (1000X) shows numerous small surface irregularities (fig.26). In contrast, surface texture following abrasion and finishing of feldspathic porcelain specimens shows increase in number and size of the surface voids/scattered pitting (fig.27). Finally after polishing with diamond polishing paste, feldspathic porcelain specimen’s shows great reduction in number and size of the surface voids/scattered pitting in case of Sof-Lex discs as compared to Autoglazing and hence exhibits a smoother surface interrupted by granularity (fig.28a). But White silicon and grey rubber showed increase in number and size of the surface voids/scattered pitting and exhibited a rougher surface as compared to Autoglazing (fig.28b).

Fig.29.2a: SEM Photomicrographs (1000x magnification) showing surface texture of the autoglazed fluorapatite leucite porcelain specimens.

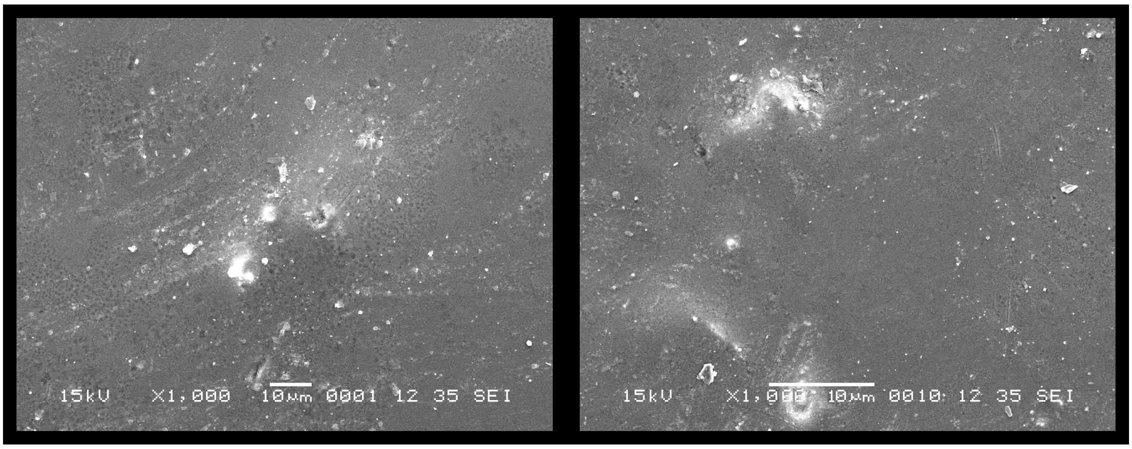
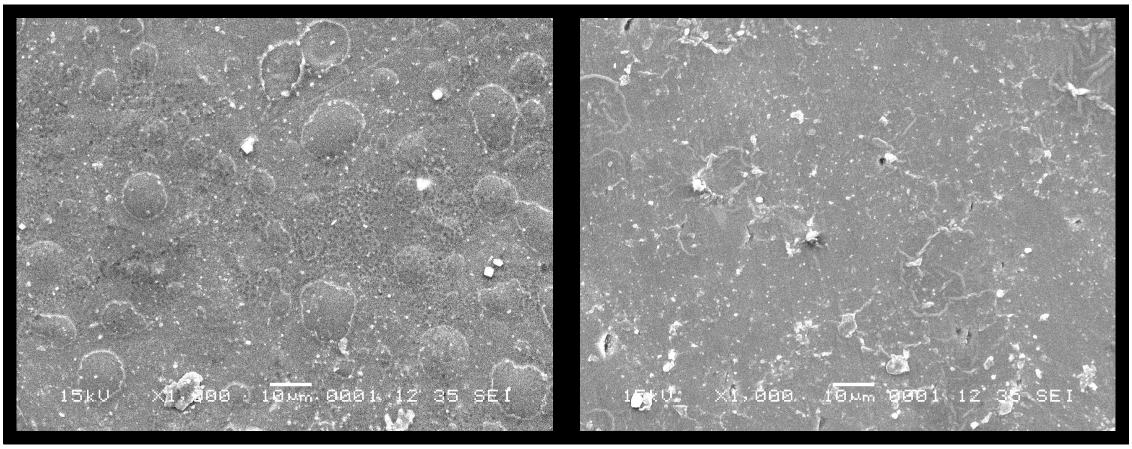


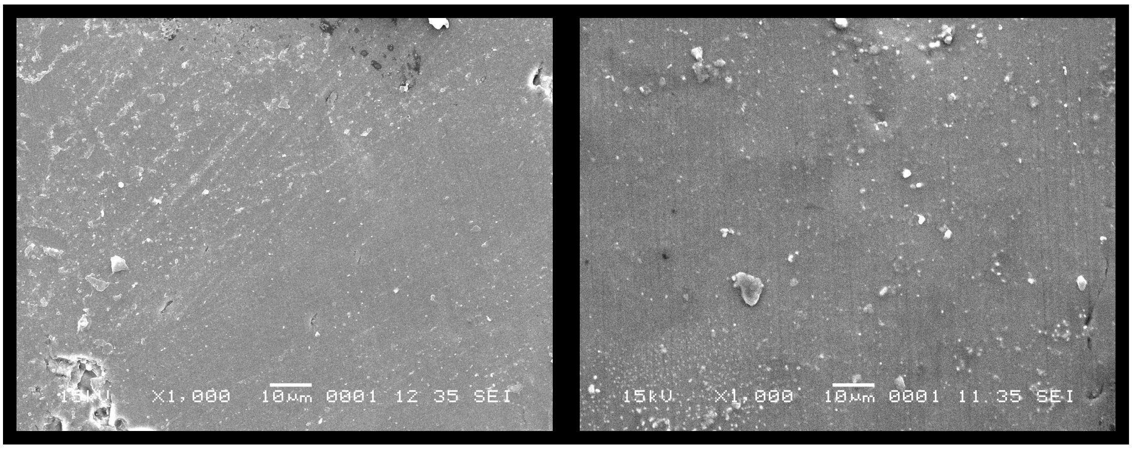
Fig.30.2b: SEM Photomicrographs (1000x magnification) showing surface texture of fluorapatite leucite porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon & grey rubber.



(a)
Sof-Lex discs

(b)
White silicon & grey rubber

Fig.31.2c: SEM Photomicrographs (1000x magnification) showing surface texture of fluorapatite leucite porcelain specimens after polishing.



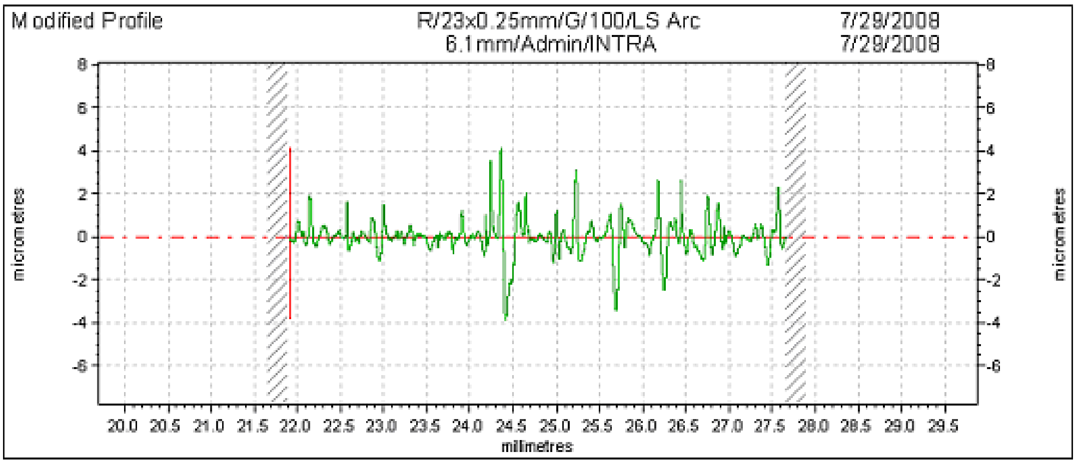
(a)
Sof-Lex discs

(b)
White silicon & grey rubber

Inference: Surface of fluorapatite leucite porcelain specimens at initial recording (Autoglazed samples), as observed under SEM (1000X) shows minimal number of imperfections as when compared to group 1a (fig.29). In contrast, surface texture following abrasion and finishing of fluorapatite leucite porcelain specimens shows increase in number and size of the surface voids/scattered pitting (fig.30). Finally after polishing with diamond polishing paste, fluorapatite leucite porcelain specimens' shows great reduction in number and size of the surface voids/scattered pitting in case of Sof-Lex discs as compared to Autoglazing and hence exhibits a smoother surface interrupted by granularity. However isolated imperfections and color dilution (milkiness) remained (fig.31a). But White silicon and grey rubber showed increase in number and size of the surface voids/scattered pitting and exhibited a rougher surface as compared to Autoglazing (fig.31b).

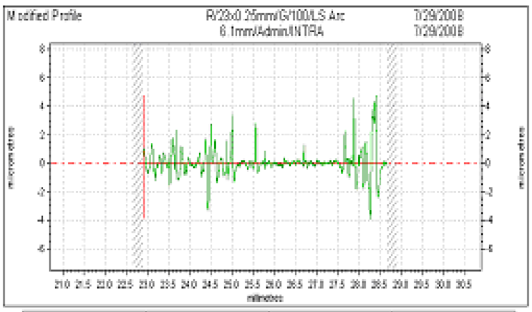
II. Quantitative analysis of surface texture of the test porcelain:

Fig.32.1d: Profilometer Photomicrographs showing surface texture (Ra value in µm) of the autoglazed feldspathic porcelain specimens.

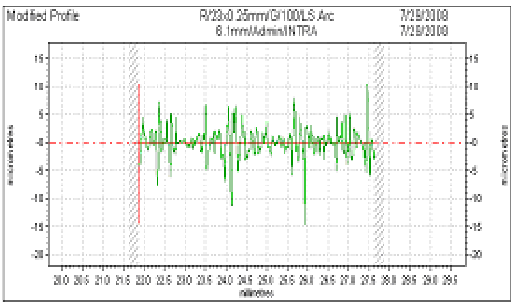


Ra = 0.52

Fig.33.1e: Profilometer Photomicrographs showing surface texture of feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon & grey rubber.



Ra = 0.54

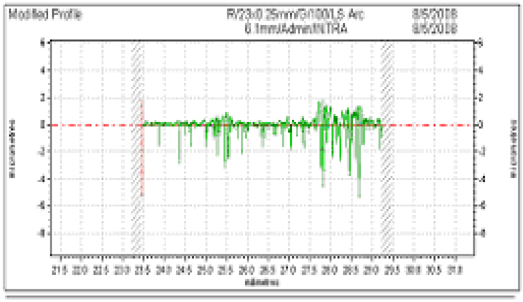


Ra = 1.25

(a) Sof-Lex discs

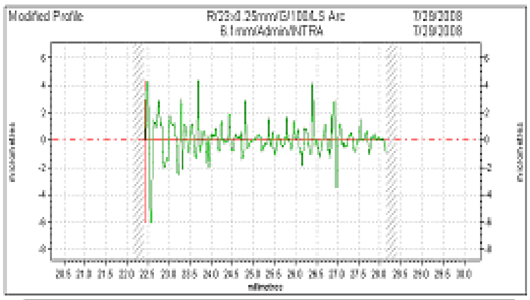
(b) White silicon & grey rubber

Fig.34.1f: ...tomicrographs ... feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon & grey rubber



Ra = 0.32

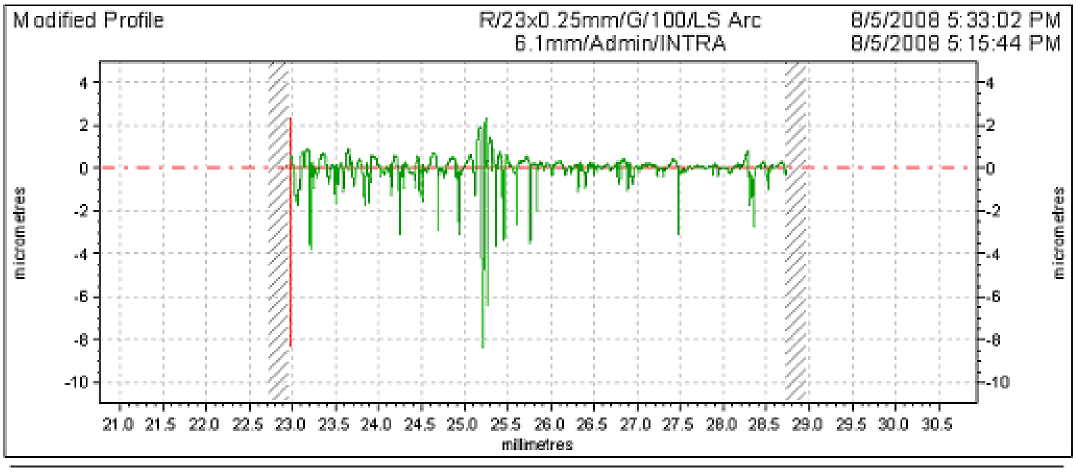
(a)
Sof-Lex discs



Ra = 0.68

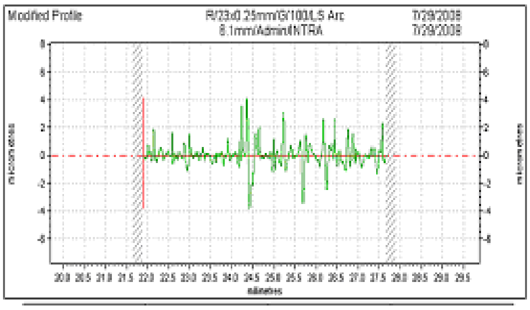
(b)
White silicon & grey rubber

Fig.35.2d: Profilometer Photomicrographs showing surface texture (Ra value in µm) of the autoglazed fluorapatite leucite porcelain specimens.



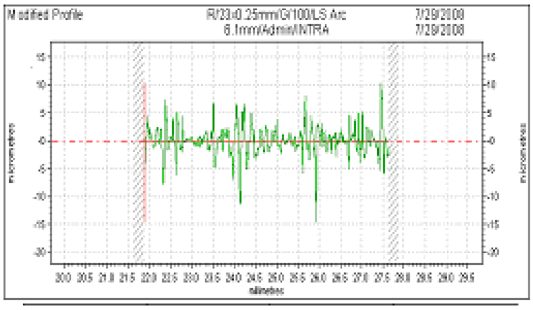
Ra = 0.40

Fig.36.2e: Profilometer Photomicrographs showing surface texture of feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon & grey rubber.



Ra = 0.52

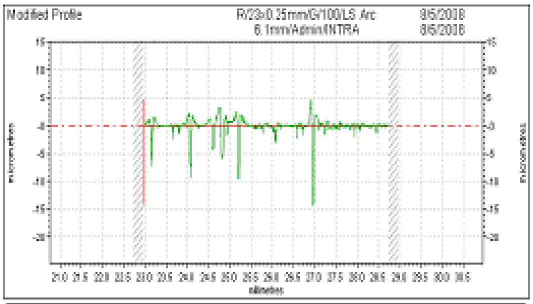
(a)
Sof-Lex discs



Ra = 1.17

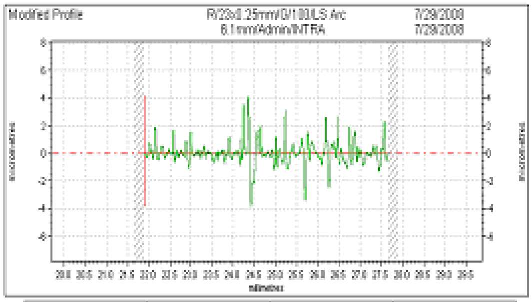
(b)
White silicon & grey rubber

Fig.37.2f: Profilometer Photomicrographs showing surface texture of feldspathic porcelain specimens following abrasion and finishing with Sof-Lex discs and White silicon & grey rubber.



Ra = 0.30

(a)
Sof-Lex discs



Ra = 0.67

(b)
White silicon & grey rubber

Tables 3,4,5, and 6 shows the basic data of the results obtained in this study of the quantitative analysis of the surface texture of two different ceramic materials for the samples in subgroups IA, IB, IIA and IIB respectively.

Table 3: IA: Surface Roughness (Ra) values in µm for the test samples of feldspathic porcelain after Autoglazing(C), following abrasion and finishing with Sof-Lex discs and finally after polishing with diamond polishing paste.

S.NO	AUTOGLAZED(C)	AFTER FINISHING(IA)	AFTER POLISHING(IA)
1.	0.55	0.60	0.35
2.	0.45	0.61	0.36
3.	0.45	0.50	0.29
4.	0.43	0.53	0.33
5.	0.58	0.46	0.28
6.	0.52	0.55	0.34
7.	0.50	0.64	0.38
8.	0.55	0.47	0.27
9.	0.56	0.50	0.30
10.	0.60	0.52	0.31

Table 4: IB: Surface Roughness (Ra) values in µm for the test samples of feldspathic porcelain after Autoglazing(C), following abrasion and finishing with White silicon and Grey rubber and finally after polishing with diamond polishing paste

S.NO	AUTOGLAZED(C)	AFTER FINISHING(IB)	AFTER POLISHING(IB)
1.	0.55	1.35	0.78
2.	0.45	1.28	0.73
3.	0.45	1.23	0.68
4.	0.43	1.18	0.70
5.	0.58	1.35	0.77
6.	0.52	1.18	0.60
7.	0.50	1.13	0.58
8.	0.55	1.12	0.58
9.	0.56	1.38	0.76
10.	0.60	1.31	0.66

Table 5: IIA: Surface Roughness (Ra) values in µm for the test samples of fluorapatite leucite porcelain after Autoglazing (D), following abrasion and finishing with Sof-Lex discs, and finally after polishing with diamond polishing paste.

S.N	AUTOGLAZED(D)	AFTER FINISHING(IIA)	AFTER POLISHING(IIA)
1.	0.38	0.48	0.29

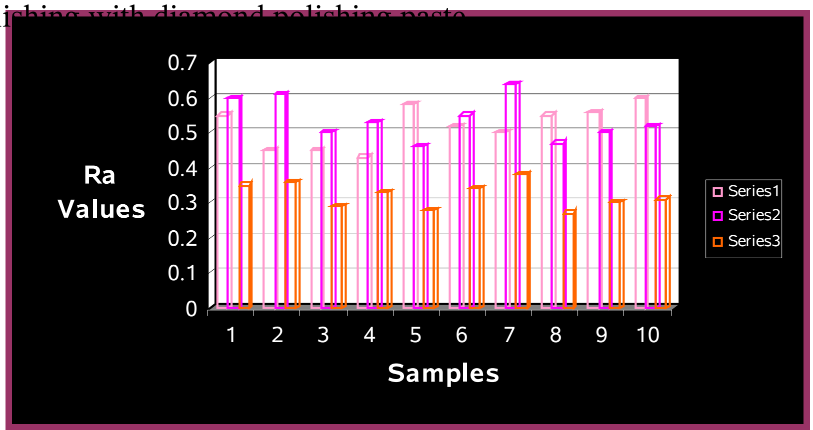
2.	**0.42**	**0.45**	**0.27**
3.	**0.39**	**0.53**	**0.31**
4.	**0.44**	**0.59**	**0.33**
5.	**0.49**	**0.58**	**0.32**
6.	**0.47**	**0.49**	**0.30**
7.	**0.34**	**0.59**	**0.35**
8.	**0.35**	**0.55**	**0.28**
9.	**0.36**	**0.45**	**0.28**
10.	**0.40**	**0.45**	**0.26**

Table 6: IIB: Surface Roughness (Ra) values in µm for the test samples of fluorapatite leucite porcelain after Autoglazing (D), following abrasion and finishing with White silicon and Grey rubber, and finally after polishing with diamond polishing paste.

S.	**AUTOGLAZED(D)**	**AFTER FINISHING(IIB)**	**AFTER POLISHING(IIB)**
1.	**0.38**	**1.12**	**0.69**
2.	**0.42**	**1.09**	**0.66**
3.	**0.39**	**1.25**	**0.78**
4.	**0.44**	**1.21**	**0.75**
5.	**0.49**	**1.27**	**0.60**
6.	**0.47**	**1.22**	**0.61**
7.	**0.34**	**1.02**	**0.67**
8.	**0.35**	**1.08**	**0.72**
9.	**0.36**	**1.25**	**0.58**
10.	**0.40**	**1.23**	**0.62**

Graphs 1, 2, 3 and 4 shows the basic data of the results obtained in this study of the quantitative analysis of the surface texture of two different ceramic materials for the samples in subgroups IA, IB, IIA and IIB respectively.

Graph1:IA: Surface Roughness (Ra) values in µm for the test samples of feldspathic porcelain after Autoglazing (C), following abrasion and finishing with Sof-Lex discs, and finally after polishing with diamond polishing paste.

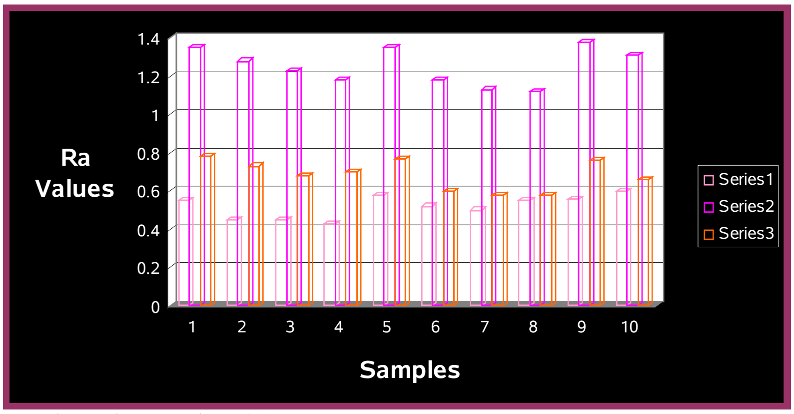


Series 1: Autoglazed samples (C)

Series 2: Samples abraded and finished with Sof-Lex discs

Series 3: Samples polished with diamond polishing paste

Graph 2: IB: Surface Roughness (Ra) values in µm for the test samples of feldspathic porcelain after Autoglazing(C), following abrasion and finishing with White silicon and Grey rubber, and finally after polishing with diamond polishing paste.

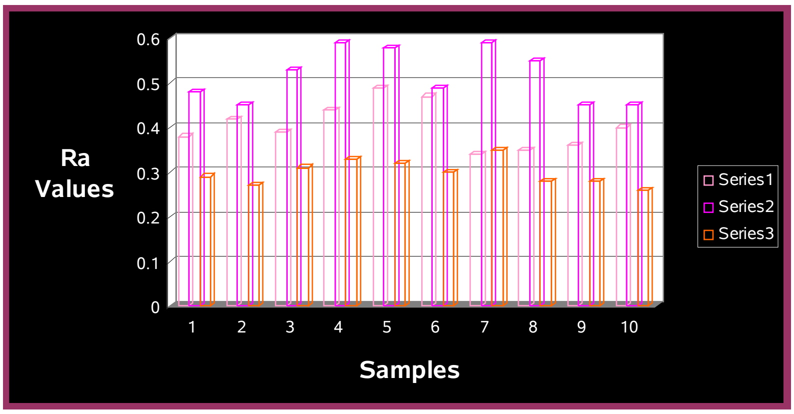


Series 1: Autoglazed samples (C)

Series 2: Samples abraded and finished with White silicon & grey rubber

Series 3: Samples polished with diamond polishing paste.

Graph 3*:* IIA: Surface Roughness (Ra) values in µm for the test samples of fluorapatite leucite porcelain after Autoglazing (D), following abrasion and finishing with Sof-Lex discs, and finally after polishing with diamond polishing paste.

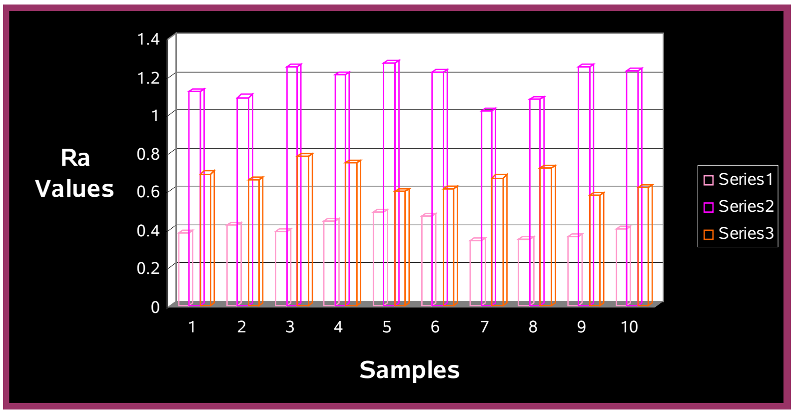


Series 1: Autoglazed samples (D)

Series 2: Samples abraded and finished with Sof-Lex discs

Series 3: Samples polished with diamond polishing paste.

Graph 4*:* IIB: Surface Roughness (Ra) values in µm for the test samples of fluorapatite leucite porcelain after Autoglazing (D), following abrasion and finishing with White silicon and Grey rubber, and finally after polishing with diamond polishing paste.



Series 1: Autoglazed samples (D)

Series 2: Samples abraded and finished with White silicon & grey rubber

Series 3: Samples polished with diamond polishing paste.

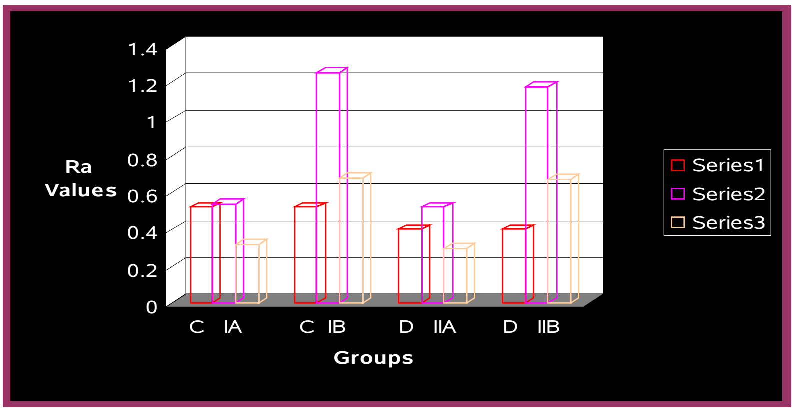
The results were subjected to statistical analysis:

Mean and standard deviations were estimated from the samples for each study group. The data were analyzed by the use of ANNOVA (Oneway Analysis of Variance) followed by Student-Newman-Keuls test. In the present study, $p<0.05$ was considered as the level of significance. Student t-Test was used to compare between the independent samples of group.

Table 7: Mean Surface Roughness (Ra) values in µm and standard deviation obtained from the basic data of test groups of Feldspathic and Fluorapatite Leucite ceramic systems.

TEST *GROUPS*	*Ra VALUES (µm)*					
	INITIAL (AUTOGLAZED)		AFTER *FINISHING*		AFTER *POLISHING*	
	MEAN	SD	MEAN	SD	MEAN	SD
C-CONTROL	0.52	0.06	------	------	------	------
IA	------	------	0.54	0.06	0.32	0.04
IB	------	------	1.25	0.10	0.68	0.08
D-CONTROL	0.40	0.05	------	------	------	------
IIA	------	------	0.52	0.06	0.30	0.03
IIB	------	------	1.17	0.09	0.67	0.07

Graph 5: Mean "Ra" values for the average surface roughness of the ceramic materials obtained from the basic data of four subgroups (IA, IB, IIA, and IIB) calculated in Micrometer (µm).



Series 1: Autoglazed samples (C & D)

Series 2: Samples abraded and finished

Series 3: Samples polished with diamond polishing paste.

Table 8, 9 and 10 shows the test of significance for the mean obtained from Autoglazed (C), and polished test samples of subgroups IA and IB of Group I (Feldspathic porcelain). Student t-Test was used to compare between the independent samples of groupI.

Table 8: Comparison between Autoglazed(C) and IA

Variable	No. of samples	Mean	SD	SE of mean
Autoglazed (C)	10	0.52	0.06	0.019
IA	10	0.32	0.04	0.012

P-value= 0.046*

Table 9: **Comparison between Autoglazed(C) and IB**

Variable	No. of samples	Mean	SD	SE of mean
Autoglazed (C)	10	0.52	0.06	0.019
IB	10	0.68	0.08	0.025

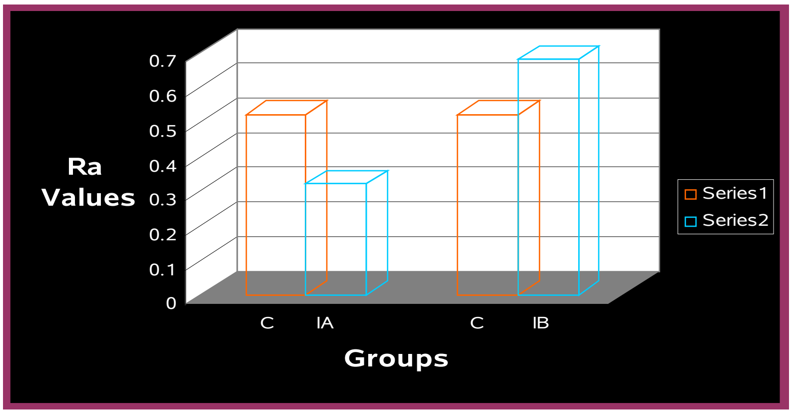
P-value= 0.001**

Table 10: Comparison between IA and IB

Variable	No. of samples	Mean	SD	SE of mean
IA	10	0.32	0.04	0.012
IB	10	0.68	0.08	0.025

P-value= 0.000**

Graph 6: Comparison of mean "Ra" values for the average surface roughness of the ceramic materials between Autoglazed(C) and polished test samples of subgroups IA and IB of Group I (Feldspathic porcelain)



Series 1: Autoglazed samples (Control)

Series 2: Samples finished and polished.

Table 11, 12 and 13 shows the test of significance for the mean obtained from Autoglazed (D), and polished test samples of subgroups IIA and IIB of Group II (Fluorapatite Leucite porcelain). Student t-Test was used to compare between the independent samples of group II.

Table 11: Comparison between Autoglazed (D) and IIA

Variable	No. of samples	Mean	SD	SE of mean
Autoglazed(D)	**10**	**0.40**	**0.05**	**0.016**
IIA	**10**	**0.30**	**0.03**	**0.009**

P-value= 0.048*

Table 12: Comparison between Autoglazed (D) and IIB

Variable	No. of samples	Mean	SD	SE of mean
Autoglazed(D)	**10**	**0.40**	**0.05**	**0.016**
IIB	**10**	**0.67**	**0.07**	**0.021**

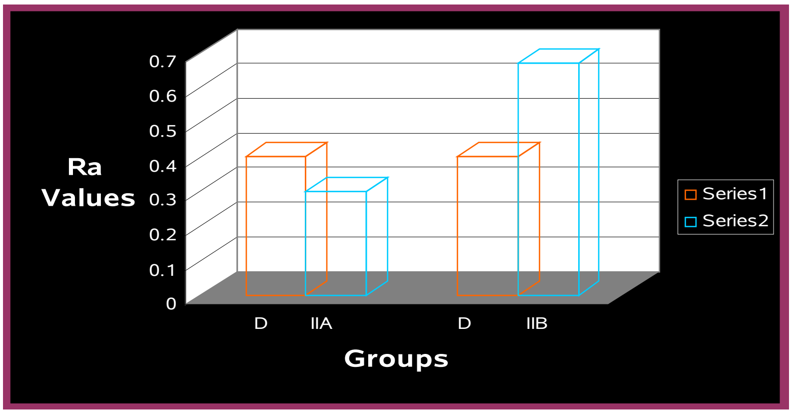
P-value= 0.001**

Table 13: Comparison between IIA and IIB

Variable	No. of samples	Mean	SD	SE of mean
IIA	**10**	**0.30**	**0.04**	**0.009**
IIB	**10**	**0.67**	**0.07**	**0.021**

P-value= 0.000**

Graph 7: Comparison of mean "Ra" values for the average surface roughness of the ceramic materials between Autoglazed (D) and polished test samples of subgroups IIA and IIB of Group II (Fluorapatite leucite porcelain).



Series 1: Autoglazed samples (Control)

Series 2: Samples finished and polished.

Table 14: Test of significance for the mean "Ra" values for the average surface roughness of the ceramic materials obtained from the subgroups IA, IB, IIA and IIB of Feldspathic and Fluorapatite leucite ceramic systems.

TEST GROUPS	Ra VALUES (µm)				P-VALUE
	INITIAL (AUTOGLAZED)		AFTER POLISHING		
	MEAN	SD	MEAN	SD	
C-CONTROL	**0.52**^{c}	**0.06**	**----**	**-----**	P **< 0.001****
IA	**-----**	**-----**	**0.32**^{a}	**0.04**	
IB	**-----**	**-----**	**0.68**^{b}	**0.08**	
D-CONTROL	**0.40**^{d}	**0.05**	**-----**	**-----**	
IIA	**-----**	**-----**	**0.30**^{a}	**0.03**	
IIB	**-----**	**----**	**0.67**^{b}	**0.07**	

Note: ** denotes significance at 1% level

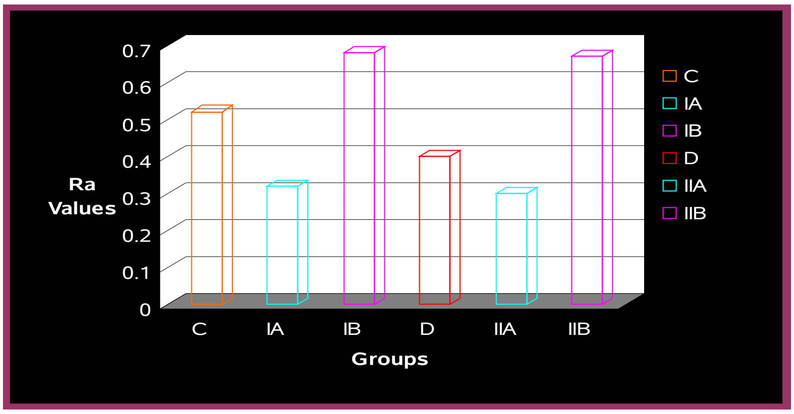
*** denotes significance at 5% level**

N.S denotes non-significance at 5% level

Different superscript letters (a, b) in mean of Ra values for average roughness of the ceramic surfaces between subgroups is significant at 1% level.

Similar superscript letters (a, a or b, b) in mean of Ra values for average roughness of the ceramic surfaces between subgroups is non-significant.

Graph 8: Comparison of mean "Ra" values for the average surface roughness of the ceramic materials between the control and subgroups IA, IB, IIA and IIB of Feldspathic and Fluorapatite leucite porcelain systems.



C: Feldspathic Autoglazed,

D: Fluorapatite Leucite Autoglazed,

IA, IIA: Samples finished (Sof-Lex discs) and polished,

IB, IIB: Samples finished (White silicon & Grey rubber) and polished.

Inference: Table 14 shows the comparison of the mean "Ra" values for the average surface roughness of the ceramic materials between the groupI and group II. Since the P value is <0.001, there is a significant difference between the two groups regarding average surface roughness.

Minimum Ra values for the average surface roughness were obtained for subgroups IA and IIA (Sof-Lex discs + Diamond polishing paste), followed by Autoglazing, and highest values were obtained with subgroups IB and IIB (White silicon & grey rubber + Diamond polishing paste). Between the two porcelain tested qualitatively in this study, the fluorapatite leucite porcelain specimens exhibited less surface roughness than feldspathic porcelain.

Multiple range tests by Student-Newman Keuls test for comparison between the groups also shows significant difference between the groups. Difference between the Autoglazed specimens and the groups finished and polished with different finishing systems showed significance at 1% level (p<0.001).

The difference between the two porcelain systems (Feldspathic and Fluorapatite Leucite) when finished with similar finishing systems, i.e. either with Sof-Lex or with White silicon and grey rubber followed by diamond polishing was non-significant. The test of significance between IA and IIA showed p-value of 0.151 and between IB and IIB showed p-value of 0.628 denoting non significant difference between the subgroups.

DISCUSSION

Dental ceramic technology is one of the fastest growing areas of dental material research and development because of its ability to closely match natural tooth color, biocompatibility, high resistance to wear and chemical inertness. These are materials of choice for all-ceramic or porcelain-fused-to-metal restorations.

In 1986 survey conducted by Christenson revealed that metal ceramic restorations account for more than 80% of the restorations made worldwide. In the simplest form of a metal ceramic crown have two major components; the metal substructure and a ceramic veneer that is mechanically and chemically bonded. The dental porcelain veneer has several discreet layers yet it functions as one mass. Consequently the metal ceramic restoration is best considered a composite entity with a metal substructure framework, a layer of opaque porcelain, dentine and enamel veneer.

Esthetic appearance of ceramic restorations is attributable to surface texture of the restoration, which is characterized by reflection and absorption of light rays. Such a desirable effect is achieved only if the surface of the restoration is optimally smooth. So the final processing step in metal ceramic restoration is to fire the complete work, to a temperature that is usually equal to or slightly higher than the original firing temperature, to produce what is often referred to as an autoglaze so that a smooth, glossy surface results.

Ideally ceramic restorations should retain their intact surface glaze. However, occasions will arise when ceramic restorations require adjustments in circumstances that preclude reglazing. For example chair side adjustment of ceramic restorations for shape, contour, occlusion and surface finish. These adjustment procedures result in loss of the autoglaze layer and create a rough surface.[3, 4, 6, 7]

Rough porcelain surface is prone to adhesion and retention of oral microorganisms. This will cause excessive plaque accumulation, gingival irritation, increased surface staining, and poor esthetics of the restored teeth and thereby increasing the risk of dental caries and periodontal disease.[6, 7] Rough occlusal porcelain is highly abrasive, causing significant wear on opposing surfaces. Monasky and Taylor demonstrated an increased potential for wear of opposing occlusal surfaces by a ground porcelain surface. According to Mc Lean JW rough porcelain surfaces also significantly reduce the strength of ceramic restorations and make them prone to fracture. Podshadley and Harrison reported that a rough porcelain surface in tissue contact can elicit an unfavorable response. Henry et al reported that glazed porcelain resulted in a most hygienic surface for all forms of ceramic restorations. In such situations, roughness must be smoothened to render the surface acceptable to the patient and make it less likely to abrade opposing tooth structure or restorative materials.

So it has been recommended by many authors that the roughened surface must be either reglazed or polished to produce the smoothest surface possible. Patterson CJ, Campbell SD initially demonstrated the superior smoothness of glazed porcelain. Others, however, favor mechanical polishing and concluded that intraoral polishing of porcelain can equal or surpass the smoothness of glazed porcelain.[19, 20, 30, 49, 51] It is recognized that improved esthetic results are obtained by polishing.[3, 9, 22, 39] The ultimate goal of mechanical finishing and polishing is the attainment of a well polished surface which can substitute for glazed porcelain. Effective finishing and polishing of dental restorations not only result in optimal aesthetics and longevity of restored teeth, but also provide for acceptable oral health of soft tissues and marginal integrity of the restorative interface.[25,26]

Adjusting, contouring, and finishing procedures for metal ceramic restorations play a critical role in achieving both proper function and optimal esthetics. Thus it has become imperative to consider the various available ceramic finishing systems to recreate the lost smoothness of the abraded surfaces to obtain optimal biocompatibility. A number of mechanical polishing techniques are described in the literature and were compared to the gold standard given by the original glaze. Studies comparing the efficacy of various smoothening and polishing systems for metal ceramic restorations are carried out either qualitatively or qualitatively. Data obtained by combined qualitative and quantitative assessment following different finishing procedures is few. Keeping the above considerations in mind, in this present study the parameter of surface texture was evaluated qualitatively and quantitatively, in two different porcelain systems using scanning electron microscope and profilometer respectively.

This in vitro study was designed to qualitatively and quantitatively evaluate and compare the effect that two different finishing systems and diamond polishing paste had on the surface texture of two different metal ceramic veneering systems. The two porcelain systems employed were Feldspathic (Group I) and Fluorapatite leucite (Group II) porcelain systems. Among the various types of porcelain available for porcelain fused to metal systems traditional feldspathic porcelain allowed systematic control of sintering temperature and thermal expansion co-efficient in harmony with the substructure alloy used. Hence feldspathic porcelain system was considered as one of the test systems. Recent attempts to overcome the wear of enamel by feldspathic porcelain have led to the introduction of fluorapatite leucite porcelain system. Fluorapatite leucite porcelain claims to have lower abrasiveness towards the enamel because of the structural arrangement of the fluorapatite crystals similar to the hydroxyl apatite crystals of the tooth enamel, better color quality and smooth surface topography. Hence fluorapatite leucite porcelain was used as the second porcelain test system in this study.

A total of twenty specimens were included in each test porcelain group I and II. Each of these twenty specimens was subjected to analysis of surface texture qualitatively and quantitatively using scanning electron microscope and profilometer respectively, following finishing with Sof-Lex discs and White silicon and grey rubber and polishing with diamond polishing paste. To obtain the metal substructure on which the two test porcelain systems could be veneered; resin patterns of 10 x 10 x 2 mm were fabricated using a custom metallic mold as required by the testing equipment employed in this study. Resin patterns were invested, subjected to a burn out and cast using Ni - Cr alloy.

In the present study the thickness of the metal substructure was 2 mm in contrast to the thickness used in most clinical situations. This was to facilitate the better handling of the test specimens as required by the testing equipment employed in this study namely the scanning electron microscope and profilometer. Studies on the effects of different finishing systems and diamond polishing paste on the surface texture of porcelain have not been adequately investigated for different metal veneered porcelain systems. Keeping this in mind feldspathic and fluorapatite leucite porcelain systems were veneered on to the metal substructure according to manufacturer's instructions. A common basic D3 shade was selected for both the porcelain systems to ensure uniformity amongst the test samples.

To ensure uniform thickness of the veneered porcelain, each sample was measured at multiple points using an Iwanson's Gauge. The excess was adjusted with sintered diamond points and then the two groups of porcelain test samples were autoglazed, according to the manufacturer's instructions and subjected to surface texture analysis qualitatively by employing a scanning electron microscope (SEM) (JEOL, ASM 6360,JAPAN) and obtaining photomicrographs at a magnification of 1000x for recording first sets of values. This is a new, state-of-the art instrument for the topographical examination of minerals, rocks, fossils and other minerals at both low and high magnifications along with a energy-dispersive detector (EDS) for analysis of unknown phases. SEM investigation also provided minor details such as voids and air bubbles, undetectable by visual inspection. SEM analysis has been employed as a tool for qualitative assessment of surface texture in a number of past documented studies. Hence in this study SEM studies were used to visualize and compare the surface profile at initial recording (Autoglazing), after abrasion and finishing and after polishing in the two porcelain test systems employed. Magnification, Kilo voltage (Kv) and tilt angle were kept constant to permit direct comparisons to be made between the resulting photomicrographs.

Similarly, the two groups of autoglazed porcelain test samples were subjected to surface texture analysis quantitatively by employing a profilometer (Taylor Hobson, Talysurf, UK) for obtaining first sets of values. Profilometer is a contact stylus instrument used to measure surface profiles and roughness. A two axis laser interferometric transducer coupled to a pivoted stylus is used to precisely measure both vertical and horizontal data of a surface using ultra software. A mean roughness profile (Ra) was determined of each specimen to describe the overall roughness of the surface. Profilometer analysis has been employed as a tool for quantitative assessment of surface texture in a number of past documented studies. Hence in this study profilometer studies were used to visualize and compare the surface profile at initial recording, after abrasion and finishing and after polishing in the two porcelain test systems employed. Resolution (Z), measuring force and traveling length and speed were kept constant to permit direct comparisons to be made between the resulting photomicrographs.

To record second sets of values, test samples of both the groups were abraded with a medium-grit sintered diamond rotary cutting instrument (Diatech Dental AG, Heerbrugg, Switzerland) with a slow- speed hand piece, rotating at approximately 10,000 rpm in a unidirectional motion with water cooling to simulate the surface conditions after an intraoral adjustments. Following abrasion with sintered diamond, out of 20 specimens of first group (Feldspathic), 10 test specimens were finished with Sof-Lex discs and designated as subgroup IA, and 10 specimens with White silicon and grey rubber and designated as IB. Similarly, for the second group (Fluorapatite leucite), 10 specimens of subgroup IIA were finished with Sof-Lex discs and 10 specimens of subgroup IIB with White silicon and grey rubber. All the test specimens of both the groups were subjected to qualitative and quantitative surface texture analysis using scanning electron microscope and profilometer respectively and the second set of values were obtained.

Finally, all the specimens of both the test group were polished by Yeti diamond paste (Yeti diamond products) along with rubber prophy cup for 30 seconds. Final set of values of their surfaces were obtained qualitatively with SEM and quantitatively using profilometer respectively.

The results obtained can be discussed under two broad categories namely (i) Qualitative surface texture analysis of the porcelain surface (ii) Quantitative surface texture analysis of the porcelain surface.

(i)Qualitative Surface texture analysis of the porcelain surface: in the present study, a qualitative comparison of the surface texture of the feldspathic and fluorapatite Leucite Porcelain systems using a Scanning Electron Microscope for observing differences at Autoglazing, following abrasion and finishing and finally after polishing showed the following results: The surface of feldspathic porcelain samples (group I) after Autoglazing(C) shows numerous small surface irregularities. In contrast, surface texture following abrasion and finishing of feldspathic porcelain samples shows increase in number and size of the surface voids/scattered pitting. Finally after polishing with diamond polishing paste, feldspathic porcelain samples shows great reduction in number and size of the surface voids/scattered pitting and hence exhibits a smoother surface interrupted by granularity.

Surface texture of fluorapatite leucite porcelain samples (group II) after Autoglazing (D) shows minimal number of imperfections as when compared to group I. In contrast, surface texture following abrasion and finishing of fluorapatite leucite porcelain samples shows increase in number and size of the surface voids/scattered pitting. Finally after polishing with diamond polishing paste, fluorapatite leucite porcelain samples shows great reduction in number and size of the surface voids/scattered pitting and hence exhibits a smoother surface. However isolated imperfections and color dilution (milkiness) remained.

The results indicate that, within the conditions of the study, surface texture of the feldspathic porcelain and fluorapatite leucite porcelain samples after finishing with Sof- Lex discs and polishing with diamond polishing paste was superior to autoglazed porcelain samples. Irregularities and generalized pitted appearance observed with autogenously glazed specimens may have been the result of uncovering of the subsurface air voids during the initial finishing procedures and later followed by an incomplete flow and coalescence of the superficial layer.

One of the objectives of glazing is to seal the open pores in the surface of fired porcelain.[3] Also glazed porcelain has been found to duplicate natural tooth surface luster and characterization.[36] Traditionally glazing has been the preferred method of restoring the surface finish to dental porcelain. Barghi et al reported that glazing procedure resulted in a significantly smoother surface than any other finishing means. However Jacobi et al. claimed that a well-polished surface was less abrasive than glazed porcelain. The results of this study are in agreement with the work of Raimondo et al, [44] who in an in vitro investigation found that two of the polishing paste systems produce a surface equal to or better than oven glazing.

Klausner et al, [30] had similar findings in favor of polishing porcelain. In their study they reported no statistically significant difference in the average roughness between the final polished surfaces and the initial autoglazed surface. The works of Monasky and Taylor and Wiley are also supportive. The findings in this study are in concurrence with the above views.

Between the two porcelain systems tested, the surface texture of the fluorapatite leucite porcelain samples when compared to feldspathic porcelain samples using SEM photomicrographs was superior.

Fluorapatite leucite porcelain being ultra low fusing porcelain is composed of fine leucite crystals dispersed in a glass matrix. It has a smaller particle size and produces a smoother surface topography when compared to the traditional feldspathic porcelain.[4] The superior surface texture of the fluorapatite leucite porcelain samples when compared to feldspathic porcelain samples can thus be attributed.

(ii) Quantitative surface texture analysis of the porcelain surface: in the present study, a quantitative comparison of the surface texture of the feldspathic and fluorapatite Leucite Porcelain systems using a Profilometer for observing differences at Autoglazing, following abrasion and finishing and finally after polishing showed the following results:

Minimum Ra values for the average roughness were obtained for subgroups IA (0.32µm) and IIA (0.30µm) (Sof-Lex discs + Diamond polishing paste), followed by Autoglazing, and highest values were obtained with subgroups IB (0.68µm) and IIB (0.67µm) (White silicon & grey rubber + Diamond polishing paste). Between the two porcelain tested in this study, the fluorapatite leucite porcelain specimens exhibited less surface roughness than feldspathic porcelain.

Fluorapatite leucite porcelain being ultra low fusing porcelain is composed of fine leucite crystals dispersed in a glass matrix. It has a smaller particle size and produces a smoother surface topography when compared to the traditional feldspathic porcelain.[4] The superior surface texture of the fluorapatite leucite porcelain samples when compared to feldspathic porcelain samples can thus be attributed. The results obtained in this study also support the above statements.

Since the P <0.001, there is a significant difference between the groups regarding average roughness. Multiple range tests by Student-Newman Keuls test for comparison between the groups also shows significant difference between the groups. Difference between the Autoglazed specimens and the groups finished and polished with different finishing systems showed significance at 1% level (p<0.001). The difference between the two porcelain systems finished and polished with similar finishing procedures is non-significant.

In the present investigation, only two porcelain systems were taken into consideration. Recently, hydrothermal low fusing porcelain system with a single glass phase and no crystal phase has been introduced to overcome the damaging wear of enamel. Further studies on the effect of finishing systems and diamond polishing paste can be undertaken between all these porcelain systems to enhance the outcome of this study. In the present study the effect of only two finishing systems (Sof-Lex discs and White silicon & grey rubber) and one polishing paste (Diamond polishing paste) were observed so further studies are needed where the impact of other finishing systems(Brasseler, Shofu-kit etc) and other polishing pastes on other porcelain systems are evaluated. Further evaluation using other finishing systems and polishing pastes may yield a confirmative result. The findings of this study can form a basis for future studies incorporating the above considerations

CONCLUSION

The following conclusions were drawn from the data obtained in this study of comparative evaluation of the effects of two ceramic finishing systems and diamond polishing paste had on the surface roughness of two ceramic materials used for ceramo-metal restorations:

1) *Qualitative analysis* of the surface texture for the test samples of *Feldspathic porcelain* after Autoglazing(C), following abrasion and finishing with Sof-Lex discs and polishing with diamond polishing paste exhibited a **reduction in the surface roughness** in comparison to Autoglazed samples. Finishing with White silicon & grey rubber and diamond polishing exhibited an **increase in the surface roughness** in comparison to Autoglazed samples.

2) *Qualitative analysis* of the surface texture for the test samples of *Fluorapatite leucite porcelain* after Autoglazing (D), following abrasion and finishing with Sof-Lex discs and polishing with diamond polishing paste exhibited a **reduction in the surface roughness** in comparison to Autoglazed samples. Finishing with White silicon & grey rubber and diamond polishing exhibited an **increase in the surface roughness** in comparison to Autoglazed samples.

3) Qualitatively the test samples of *Fluorapatite leucite porcelain* exhibited **less surface roughness** after Autoglazing, following abrasion and finishing with two test finishing systems and finally after polishing with diamond polishing paste as compared to those of the Feldspathic porcelain system.

4) *Quantitative analysis* of the surface texture for the test samples of *Feldspathic porcelain* after Autoglazing(C), following abrasion and finishing with Sof-Lex discs and polishing with diamond polishing paste exhibited a significant **reduction in the surface roughness** with a

mean Ra value of 0.32 µm in comparison to Autoglazed samples having mean Ra value of 0.52 µm. Finishing with White silicon & grey rubber and diamond polishing exhibited a significant **increase in the surface roughness** where the mean Ra value was found to be 0.68 µm in comparison to Autoglazed samples having mean Ra value of 0.52 µm.

5) *Quantitative analysis* of the surface texture for the test samples of *Fluorapatite leucite porcelain* after Autoglazing (D), following abrasion and finishing with Sof-Lex discs and polishing with diamond polishing paste exhibited a significant **reduction in the surface roughness** with a mean Ra value of 0.30 µm in comparison to Autoglazed samples having mean Ra value of 0.40 µm. Finishing with White silicon & grey rubber and polishing exhibited a significant **increase in the surface roughness** where the mean Ra value was found to be 0.67 µm in comparison to Autoglazed samples having mean Ra value of 0.40µm.

6) Quantitatively the test samples of *Fluorapatite leucite porcelain* exhibited significantly **lesser surface roughness** values after Autoglazing, following abrasion and finishing with two test finishing systems and finally after polishing with diamond polishing paste as compared to those of the Feldspathic porcelain system. Between the groups $P < 0.001$, denoting significance at 1% level.

7) The surface roughness values obtained by *qualitative and quantitative analysis* of Feldspathic and the Fluorapatite leucite porcelain systems **are in correlations to each other**.

SUMMARY

This in vitro study was done to qualitatively and quantitatively evaluate and compare the effect of two ceramic finishing systems and diamond polishing paste had on the surface texture of two ceramic materials namely Feldspathic and Fluorapatite leucite used for ceramo-metal restorations:

A total of 40 resin patterns were fabricated with custom metallic mold, invested and were cast in nickel chromium alloy with induction casting machine. The metal substructure thus obtained were finished, then sandblasted and assigned into 2 groups with 20 specimens for each porcelain system that were subsequently veneered with, D3 shade of Feldspathic and Fluorapatite leucite porcelain systems respectively.

All the test specimens were autoglazed according to the manufacturer's instructions and subjected to qualitative and quantitative surface texture analysis using scanning electron microscope and profilometer respectively for the first reading. Following abrasion with sintered diamond, out of 20 specimens of first group (Feldspathic), 10 test specimens were finished with Sof-Lex discs and 10 specimens with White silicon and grey rubber. Similarly, for the second group (Fluorapatite leucite), 10 specimens were finished with Sof-Lex discs and 10 specimens with White silicon and grey rubber, following abrasion with sintered diamond. All the test specimens were subjected to qualitative and quantitative surface texture analysis using scanning electron microscope and profilometer respectively for the second reading. Finally the entire test specimens of both groups were polished using diamond polishing paste with rubber prophy cup, and surface texture of all the samples were qualitatively and quantitatively analyzed using scanning electron microscope and profilometer for the third reading. The results obtained were tabulated and statistically analyzed.

When qualitatively and quantitatively assessed, the surface texture was observed to be smoothest for all the test specimens finished and polished with Sof-Lex discs and diamond polishing paste respectively, followed by autoglazed specimens and least in this sequence were the specimens finished and polished with White silicon & grey rubber and diamond polishing paste respectively. Between the two porcelain systems tested in this study, the Fluorapatite leucite porcelain specimens exhibited better surface smoothness than Feldspathic porcelain.

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